



IMPERIAL INSTITUTE  
OF  
AGRICULTURAL RESEARCH, PUSA.





JOURNAL  
AND  
PROCEEDINGS  
OF THE  
ROYAL SOCIETY  
OF  
NEW SOUTH WALES  
FOR  
1931.  
(INCORPORATED 1881.)

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VOL. LXV.

EDITED BY  
THE HONORARY SECRETARIES.

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THE AUTHORS OF PAPERS ARE ALONE RESPONSIBLE FOR THE STATEMENTS  
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SYDNEY  
PUBLISHED BY THE SOCIETY, SCIENCE HOUSE, GLOUCESTER AND  
ESSEX STREETS, SYDNEY.

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1932.





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1

THE ROYAL SOCIETY of New South Wales originated in 1821 as the "Philosophical Society of Australasia"; after an interval of inactivity, it was resuscitated in 1850, under the name of the "Australian Philosophical Society," by which title it was known until 1856, when the name was changed to the "Philosophical Society of New South Wales"; in 1866, by the sanction of Her Most Gracious Majesty Queen Victoria, it assumed its present title, and was incorporated by Act of the Parliament of New South Wales in 1881.

TO AUTHORS.

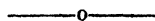
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[Those persons who feel disposed to benefit the Royal Society of New South Wales by Legacies, are recommended to instruct their Solicitors to adopt the above Form of Bequest.]

# PUBLICATIONS



The following publications of the Society, if in print, can be obtained at the Society's Rooms, Science House, Gloucester and Essex Streets, Sydney.

Transactions of the Philosophical Society, N.S.W., 1862-5, pp. 374, out of print.  
 Vols. I—XI Transactions of the Royal Society, N.S.W., 1867—1877 „

„	XII	Journal and Proceedings	„	„	1878, pp. 324, price 10s. 6d.	„
„	XIII	„	„	„	1879, „ 255,	„
„	XIV	„	„	„	1880, „ 391,	„
„	XV	„	„	„	1881, „ 440,	„
„	XVI	„	„	„	1882, „ 327,	„
„	XVII	„	„	„	1883, „ 324,	„
„	XVIII	„	„	„	1884, „ 224,	„
„	XIX	„	„	„	1885, „ 240,	„
„	XX	„	„	„	1886, „ 396,	„
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„	XXIV	„	„	„	1890, „ 290,	„
„	XXV	„	„	„	1891, „ 348,	„
„	XXVI	„	„	„	1892, „ 426,	„
„	XXVII	„	„	„	1893, „ 530,	„
„	XXVIII	„	„	„	1894, „ 368,	„
„	XXIX	„	„	„	1895, „ 600,	„
„	XXX	„	„	„	1896, „ 568,	„
„	XXXI	„	„	„	1897, „ 626,	„
„	XXXII	„	„	„	1898, „ 476,	„
„	XXXIII	„	„	„	1899, „ 400,	„
„	XXXIV	„	„	„	1900, „ 484,	„
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„	XLV	„	„	„	1911, „ 611,	„
„	XLVI	„	„	„	1912, „ 275,	„
„	XLVII	„	„	„	1913, „ 318,	„
„	XLVIII	„	„	„	1914, „ 584,	„
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„	LXII	„	„	„	1928, „ 458,	„
„	LXIII	„	„	„	1929, „ 263,	„
„	LXIV	„	„	„	1930, „ 434,	„
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# LIST OF THE MEMBERS

## OF THE

# Royal Society of New South Wales.

P Members who have contributed papers which have been published in the Society Journal. The numerals indicate the number of such contributions.

‡ Life Members.

Elected.

1908		Abbott, George Henry, B.A., M.B., CH.M., 185 Macquarie-street p.r. 'Cooringa,' 252 Liverpool Road, Summer Hill.
1904		Adams, William John, M.I.Mech.E., 175 Clarence-street.
1898		Alexander, Frank Lee, William-street, Granville.
1905	P 3	Anderson, Charles, M.A., D.Sc. <i>Edin.</i> , Director of the Australian Museum, College-street. (President, 1924.)
1909	P 9	Andrews, Ernest C., B.A., F.G.S., Hon. Mem. Washington Academy of Sciences, Government Geologist, Department of Mines, Sydney: p.r. 32 Benelong Crescent, Bellevue Hill (President, 1921.)
1930		Aston, Ronald Leslie, B.Sc., B.E. <i>Syd.</i> , M.Sc. <i>Cantab.</i> , Lecturer in Civil Engineering and Surveying in the University of Sydney, 24 Redmyre Road, Strathfield.
1919		Aurousseau, Marcel, B.Sc., No. 65A Market-lane, Manly.
1923		Baccarini, Antonio, Doctor in Chemistry <i>Florence</i> , c/o Dante, Alighieri Society, Box 1168, G.P.O. Sydney.
1878		Backhouse, His Honour Judge A. P., M.A., 'Melita,' Elizabeth Bay.
1924		Bailey, Victor Albert, M.A., D.Phil., F.Inst.P., Assoc.-Professor of Physics in the University of Sydney.
1919		Baker, Henry Herbert, Watson House, Bligh-street, Sydney.
1894	P 28	Baker, Richard Thomas, 'The Crescent,' Cheltenham.
1926		Bannon, Joseph, B.Sc. Demonstrator in Physics in the University of Sydney; p.r. 'Dunisla,' The Crescent, Homebush.
1919		Bardsley, John Ralph, 'The Pines,' Lea Avenue, Five Dock.
1925		Barker-Woden, Lucien, F.R.G.S., Commonwealth Department of Navigation, William Street, Melbourne
1908	P 1	Barling, John, L.S., 'St. Adrians,' Raglan-street, Mosman.
1895	P 9	Barracough, Sir Henry, K.B.E., B.E., M.M.E., M. Inst. C.E., M. I. Mech. E., Memb. Soc. Promotion Eng. Education; Memb. Internat. Assoc. Testing Materials; Dean of the Faculty of Engineering and Professor of Mechanical Engineering in the University of Sydney.
1929		Baur, Fidel George, M.D., Ophthalmic Surgeon, 213 Macquarie-street, Sydney.
1909	P 2	Benson, William Noel, B.Sc. <i>Syd.</i> , B.A. <i>Cantab.</i> , F.G.S., Professor of Geology in the University of Otago, Dunedin, N.Z.
1926		Bentivoglio, Sydney Ernest, B.Sc. <i>Arg.</i> , c/o Tooth and Co., Limited, Sydney; p.r., 14 Gordon Avenue, Coogee.



# X.

## Elected.

- 1919 Bettley-Cooke, Hubert Vernon, F.C.S., A.A.C.I., 'The Hollies,' Minter-street, Canterbury.
- 1923 Birks, George Frederick, c/o Potter & Birks, 15 Grosvenor-street
- 1916 Birrell, Septimus, Appian Way, Hurwood.
- 1920 Bishop, Eldred George, 8 Belmont-road, Mosman.
- 1915 Bishop, John, 12 O'Connell-street.
- 1923 P 4 Blakely, William Faris, 'Myola,' Florence-street, Hornsby.
- 1905 Blakemore, George Henry, "Wawoona," 10 Cooper Street, Strathfield.
- 1888 †Blaxland, Walter, F.R.C.S. Eng., L.R.C.P. Lond., 'Inglewood,' Florida Road, Palm Beach, Sydney.
- 1926 P 4 Booker, Frederick Wilham, B.Sc., 'Dunkeld,' Nicholson-street, Chatawood.
- 1920 P 4 Booth, Edgar Harold, M.C., B.Sc., F.Inst.P., Lecturer and Demonstrator in Physics in the University of Sydney.
- 1922 Bradfield, John Job Crew, D.Sc. Eng., M.E., M.Inst.C.E., M.Inst.E. Aust., Chief Engineer, Metropolitan Railway Construction, Railway Department, Sydney.
- 1926 Branch, Kenneth James F., 99 Ocean Beach, Manly.
- 1917 Breakwell, Ernest, B.A., B.Sc., Dept. of Education, Box 88 A, G.P.O., Sydney.
- 1891 Brennand, Henry J. W., B.A., M.D., Ch.M. Syd., V.D., Surgeon Commander R.A.N. Ret., 223 Macquarie-street; p.r. 73 Milsons Road, Cremorne.
- 1923 Brereton, Ernest Le Gay, B.Sc., Lecturer and Demonstrator in Chemistry in the University of Sydney.
- 1919 P 1 Briggs, George Henry, B.Sc., Ph.D., Assistant-Professor of Physics in the University of Sydney.
- 1923 Brown, Herbert, 'Sikoti,' Alexander-street, Collaroy Beach, Sydney.
- 1906 Brown, James B., St. Andrew's, No 1 Maitland Avenue, East Kew, E. 4, Victoria.
- 1913 P 17 Browne, William Rowan, D.Sc., Assistant-Professor of Geology in the University of Sydney.
- 1898 †Burfitt, W. Fitzmaurice, B.A., M.B., Ch.M. B.Sc. Syd., 'Wyoming,' 175 Macquarie-street, Sydney.
- 1926 Burkitt, Arthur Neville St. George, M.B., B.Sc., Professor of Anatomy in the University of Sydney.
- 1919 P 10 Burrows, George Joseph, B.Sc., Lecturer and Demonstrator in Chemistry in the University of Sydney; p.r. Watson-street, Neutral Bay.
- 1929 Caley, Gilbert Fatkin, Manager, Glycerine Distillery Co., Ltd., Alexandria; p.r. 'WindyrIDGE,' Park Road, Auburn.
- 1929 P 1 Callaghan, Allan Robert, D.Phil., B.Sc., (Oxon.), B.Sc. Agr., Plant Breeder, Wagga Experiment Farm, Bomen, N.S.W.
- 1909 Calvert, Thomas Copley, Assoc.M.Inst.C.E., c/o Dept. of Public Works, Newcastle, N.S.W.
- 1923 Cameron, Lindsay Duncan, Hilly-street, Mortlake.
- 1891 Carment, David, F.I.A. Grt. Brit. & Irel. & F.F.A., Scot., 4 Whaling Road, North Sydney.
- 1920 Carnuthers, Sir Joseph Hector, K.C.M.G., M.T.C., M.A., Syd., LL.D., St. Andrews, 'Highbury,' Waverley.

## Elected

- 1908 P 3 Carslaw, Horatio S., M.A., Sc.D., Professor of Mathematics in the University of Sydney.
- 1918 P 3 Challinor, Richard Westman, F.I.C., F.C.S., Lecturer in Chemistry, Sydney Technical College.
- 1909 P 2 Chapman, Henry G., M.D., B.S., Director of Cancer Research, University of Sydney. *Hon. Treasurer.*
- 1913 P 18 Cheel, Edwin, Curator, National Herbarium, Botanic Gardens, Sydney. *President.*
- 1925 P 1 Clark, William E., High School, Armidale.
- 1909 P 20 Cleland, John Burton, M.D., Ch.M., Professor of Pathology in the University of Adelaide. (President 1917.)
- 1896 P 4 Cook, W. E., M.C.E., *Melb.*, M.Inst.C.E., Burroway St., Neutral Bay.
- 1920 Cooke, Frederick, c/o Meggitt's Limited, Asbestos House, York and Barrack streets, Sydney.
- 1913 P 4 Coombs, F. A., F.C.S., Instructor of Leather Dressing and Tanning, Sydney Technical College; p.r. Bannerman Crescent, Rosebery.
- 1928 Coppleson, Victor Marcus, M.B., Ch.M., F.R.C.S., 225 Macquarie-street, Sydney.
- 1882 Cornwell, Samuel, J.P., 'Capanesk,' Tyagarah, North Coast.
- 1919 Cotton, Frank Stanley, B.Sc., Chief Lecturer and Demonstrator in Physiology in the University of Sydney.
- 1909 P 7 Cotton, Leo Arthur, M.A., D.Sc., Professor of Geology in the University of Sydney. *Vice-President* (President 1929.)
- 1892 P 1 Cowdery, George R., Assoc.M.Inst.C.E., 'Glencoe,' Torrington Road, Strathfield.
- 1886 Crago, W. H., M.R.C.S. Eng., L.R.C.P. Lond., 135 Macquarie-st.
- 1921 P 1 Cresswick, John Arthur, 101 Villiers-street, Rockdale.
- 1925 Curry, Harris Eric Marshall, 8 Lower Wycombe-road, Neutral Bay.
- 1912 Curtis, Louis Albert, L.S., F.R.S. (N.S.W.), v.d., Room 618, Government Savings Bank Building, Castlereagh-street; p.r. No. 1 Mayfair Flats, Mackeney-street, Darlinghurst.
- 1890 Dare, Henry Harvey, M.E., M.Inst.C.E., Commissioner, Water Conservation and Irrigation Commission, Department of Agriculture Building, Raphael-street, Sydney.
- 1886 P 23 David, Sir Edgeworth, K.B.E., C.M.G., D.S.O., B.A., D.Sc., F.R.S., F.G.S., Wollaston Medallist, Emeritus Professor of Geology and Physical Geography in the University of Sydney; p.r. 'Coringah,' Burdett-street, Hornsby. (President 1895, 1910.)
- 1928 Davidson, Walter Charles, General Manager, Clyde Engineering Company, Granville.
- 1930 Davies, Harold Whitridge M.B., B.S. *Adel.*, Professor of Physiology in the University of Sydney.
- 1919 P 2 de Beuzeville, Wilfrid Alex. Watt, J.P., 'Mélamere,' Welham-street, Beecroft, N.S.W.
- 1921 Delprat, Guillaume Daniel, C.B.E., 'Keynsham,' Mandeville Crescent, Toorak, Victoria.
- 1921 Denison, Sir Hugh Robert, K.B.E., 701 Culwulla Chambers, Castlereagh-street.
- 1894 Dick, James Adam, C.M.G., B.A. *Syd.*, M.D., Ch.M., F.R.C.S. *Edin.*, 'Cattoss,' 59 Belmore Road, Randwick.

## Elected

1906		†Dixon, William, 'Meridong,' Gordon Road, Killara.
1913	P 3	Doherty, William M., FIC, FCS, Second Government Analyst, pr 'Jesmond,' George-street, Marrickville
1928		Donegan, Henry Arthur James, A.S.T.C., Chemical Laboratory, Department of Mines, Sydney
1908	P 6	Dun, William S., Palaeontologist, Department of Mines, Sydney. (President 1918)
1924		Dupain, George Zephirin, A.A.C.T., F.C.S., Dupain Institute of Physical Education, Manning Building, Pitt and Hay Streets, Sydney, pr 'Symington,' Parramatta Road, Ashfield.
1924		Durham, Joseph, 120 Belmore Road, Randwick
1928	P 9	Earl, John Campbell, D.Sc. Ph.D., Professor of Organic Chemistry in the University of Sydney
1919		Earp, The Hon George Frederick, C.B.E., M.L.C., Australia House, 52 Carrington-street
1924		Eastaugh, Frederick Alldis, A.R.S.M., F.I.C., Assoc Professor in Chemistry Assaying and Metallurgy in the University of Sydney
1916	P 2	Enright, Walter J., B.A., High-street, West Maitland, N.S.W.
1908		Esdaile, Edward William, 42 Hunter-street
1921		Farnworth, Henry Gordon, 'Rothsay,' 90 Alt-street, Ashfield.
1910		Farrall, John, A.I.C., Syd, Riverina Flats, 265 Palmer-street, Sydney
1909	P 7	Fawsitt, Charles Edward, D.Sc. Ph.D., Professor of Chemistry in the University of Sydney (President 1919)
1922		Ferguson, Andrew
1927	P 3	Finnemore Horace, B.Sc., F.I.C., Lecturer in Pharmacy in the University of Sydney
1923		Fiaschi, Piero, O.B.E. M.D. Columbia Univ D.D.S. New York, M.R.C.S. Eng. L.R.C.P. Lond, 178 Philip-street
1920		Fisk Ernest Thomas, Wireless House, 47 York-street
1888		Fitzhardinge, His Honour Judge G.H., M.A. 'Red Hill,' Pennant Hills
1879		†Foreman, Joseph, M.R.C.S. Eng. L.R.C.P. Edin, 'The Astor,' Macquarie street
1920		Fortescue, Albert John, 'Benambra,' Loftus-street, Arncliffe.
1905		Foy, Mark, c/o Hydro Office, Liverpool and Elizabeth streets, Sydney
1925		Friend, Norman Bartlett, 48 Pile-street, Dulwich Hill
1918		Gallagher, James Laurence, M.A. Syd, 'Akaroa,' Ellesmere Avenue, Hunter's Hill
1926		Gibson, Alexander James, M.E., M.Inst.C.E., M.I.E.Aust, 906 Culwulla Chambers Castlereagh-street, Sydney
1921		Godfrey, Gordon Hay, M.A., B.Sc. Lecturer in Physics in the Technical College, Sydney, pr "Eversham," Victoria Parade, Manly

## Elected

1897		Gould, The Hon. Sir Albert John, K.B., v.d., 'Eynesbury,' Edgecliff.
1922	P 2	Greig, William Arthur, Mines Department, Sydney.
1923		Gurney, William Butler, B.Sc., F.E.S., Government Entomologist, Department of Agriculture, Sydney.
1890	P 5	Halligan, Gerald H., L.S., F.G.S., "Geraldine," Culworth Avenue, Killara.
1912		Hallmann, E. F., B.Sc., 72 John-street, Petersham.
1892		Halloran, Henry Ferdinand, L.S., 82 Pitt-street.
1919		Hambridge, Frank, Adelaide Steamship Co. Chambers, 22 Bridge-street, Sydney.
1912		Hamilton, Alexander G., 'Tanandra,' Hercules-st., Chatswood.
1909		Hammond, Walter L., B.Sc., High School, Bathurst.
1905	P 5	Harker, George, D.Sc., F.A.C.I., 57 Junction-street, Summer Hill.
1913	P 1	Harper, Leslie F., F.G.S., Geological Surveyor, Department of Mines, Sydney.
1923	P 1	Harrison, Travis Henry, B.Sc. Agr., Lecturer in Entomology and Botany, at the Hawkesbury Agricultural College, Richmond; p.r. 17 Hurlstone-avenue, Summer Hill.
1918		Hassan, Alex. Richard Roby.
1929		Hawley, Joseph William, 15 Springdale-road, Killara.
1914		Hector, Alex. Burnet, "Druminard," Greenwich-road, Greenwich.
1916		Henderson, James, 'Dunstfold,' Clanalpine-street, Mosman.
1919		Henriques, Frederick Lester, 208 Clarence-street.
1919	P 2	Henry, Max, D.S.O., B.V.Sc., M.R.C.V.S., Chief Veterinary Surgeon, Dept. Agriculture, Sydney. p.r. 'Coram Cottage,' Essex-street, Epping.
1918		Hindmarsh, Percival, M.A., B.Sc. Agr., Teachers' College, The University, Sydney; p.r. 'Lurnea,' Canberra Avenue, Greenwich.
1921	P 2	Hindmarsh, William Lloyd, B.V.Sc., M.R.C.V.S., D.V.H., District Veterinary Officer, Glenfield.
1928		Hirst, George Walter Cansdell, B.Sc., Chief Mechanical Engineer's Office, N.S.W. Govt. Railways, Wilson Street, Redfern; p.r. 'St Cloud,' Beaconsfield-road, Chatswood.
1930		Hodson, John S., Electrical Engineer, H.M. Naval Establishments, Garden Island, Sydney.
1916		Hoggan, Henry James, A.M.I.M.E., A.M.I.E. Aust., Manchester Unity Chambers, 160 Castlereagh-street; p.r. 'Lincluden,' Frederick-street, Rockdale.
1924		Holme, Ernest Rudolph, O.B.E., M.A., Professor of English Language in the University of Sydney.
1930		Holmes, James MacDonald, Associate Professor of Geography in the University of Sydney.
1901		Holt, Thomas S., 'Amalfi,' Appian Way, Burwood.
1905	P 3	Hooper, George, J.P., F.T.C. Syd., 'Mycumbene,' Nielsen Park, Vaucluse.
1919		Hoskins, Arthur Sidney, Eskroy Park, Bowenfels.
1919		Hoskins, Cecil Harold, c/o Australian Iron and Steel Co., Ltd., Kembla Building, Margaret-street, Sydney.
1913		Hudson, G. Inglis, J.P., F.C.S., 180 Arden-st., Coogee.

xiv.

Elected

1923	P 2	Hynes, Harold John, M.Sc., B.Sc. Agr., Senior Asst. Biologist, Department of Agriculture, Sydney.
1927		Inglis, William Keith, M.D., Ch.M., Lecturer in Pathology in the University of Sydney; p.r. 84 Wolseley-street, Drummoyne.
1922		Jacobs, Ernest Godfried, 'Cambria,' 106 Bland-street, Ashfield.
1904		Jaquet, John Blockley, A.R.S.M., F.G.S., Chief Inspector of Mines, Department of Mines, Sydney.
1929		Jeffrey, Robert Ewen, A.A.C.I., Managing Director, Bardsley's Ltd.; p.r. 9 Greycliff-avenue, Vacluse.
1925		Jenkins, Charles Adrian, B.E., B.Sc., 2 Ramsgate Avenue, Bondi Beach.
1917		Jenkins, Richard Ford, Engineer for Boring, Irrigation Commission 6 Union-street, Mosman.
1918		John, Morgan Jones, M.I.Mech.E., A.M.I.E.E. Lond., M.I.E. Aust., M.I.M. Aust., p.r. Village High Road Vacluse.
1909	P 15	Johnston, Thomas Harvey, M.A., D.Sc., F.L.S., C.M.Z.S., Professor of Zoology in the University of Adelaide.
1924		Jones, Leo Joseph, Geological Surveyor, Department of Mines, Sydney.
1930		Judd, William Percy, 49 Hirst Street, Arncliffe.
1911		Julius, George A., Sir, Kt., B.Sc., M.E., M.I.Mech.E., Culwulla Chambers, Castlereagh-street, Sydney.
1924		Kenny, Edward Joseph, Geological Surveyor, Department of Mines, Sydney; p.r. 5 Savings Bank Flats, Bondi Beach.
1887		Kent, Harry C., M.A., F.R.I.B.A., 35 Beresford Road, Rose Bay.
1919	P 3	Kesteven, Hereward Leighton, M.D., Ch.M., D.Sc., Bulladelah, New South Wales.
1896		King, Kelso, Sir, K.B., Mercantile Mutual Building, 117 Pitt-street, Sydney.
1923		Kinghorn, James Roy, Australian Museum, Sydney.
1920		Kirchner, William John, B.Sc., "Wanawong," Thornleigh-road, Beecroft.
1919		Kirk, Robert Newby, 25 O'Connell-street
1877		Knox, Edward W., 'Rona,' Bellevue Hill, Double Bay.
1924		Leech, Thomas David James, B.Sc. Syd., 'Orontes,' Clarke-st., Granville.
1920		Le Souef, Albert Sherbourne, Taronga Park, Mosman.
1916		L'Estrange, Walter William, 7 Church-street, Ashfield.
1909		Leverrier, Frank, B.A., B.Sc., K.C., Wentworth Road, Vacluse.
1883		Lingen, J. T., M.A. Cantab., K.C., c/o Union Club, Bligh-st.

Elected

1929	P 3	Lions, Francis, B.Sc., Ph.D., Lecturer in Organic Chemistry in the University of Sydney, p.r., 21 Bridge-street, Epping.
1906		Loney, Charles Augustus Luxton, M.Am Soc.Refr E., National Mutual Building, 350 George-street.
1924		Love, David Horace, Beauchamp Avenue, Chatswood
1927		Love, William Henry, B.Sc., "Lumeah," 9 Miller-street, Haberfield.
1884		MacCormick, Sir Alexander, K.C.M.G., M.D., C.M. <i>Edm.</i> , M.R.C.S. <i>Eng.</i> , 185 Macquarie-street.
1980		MacKenzie, William Donald, M.I.Chem E., A.I.C., Technical Director, Messrs Lever Bros. Ltd., Balmain
1921		McDonald, Alexander Hugh Earle, Director of Agriculture, Department of Agriculture, Sydney.
1903		McDonald, Robert, J.P., L.S., Pastoral Chambers, O'Connell-st; p.r. 'Lowlands,' William-street, Double Bay
1919		McGeachie, Duncan, M.I.M.E., M.I.E. <i>Aust.</i> , M.I.M.E. <i>Aust.</i> , 'Craig Royston,' Toronto, Lake Macquarie.
1906	P 2	McIntosh, Arthur Marshall, 'Moy Lodge,' Hill-st., Roseville.
1891		McKay, R. T., L.S., M.Inst.C.E., Commissioner, Sydney Harbour Trust, Circular Quay.
1927		McMaster, Frederick Duncan, "Dulkeith," Cassilis
1916		McQuiggin, Harold G., M.B., Ch.M., B.Sc. Lecturer and Demonstrator in Physiology in the University of Sydney; p.r. 'Berolyn,' Beaufort-street, Croydon.
1909		Madsen, John Percival Vissing, D.Sc., B.E., Professor of Electrical Engineering in the University of Sydney.
1924		Mance, Frederick Stapleton Under Secretary for Mines, Mines Department Sydney; p.r. 'Binbah,' Lucretia Avenue, Longueville.
1880	P 1	Manfred, Edmund C., Belmore-square, Goulburn
1920	P 1	Mann, Cecil William, 41 Jenkin street, Chatswood.
1920		Mann, James Elliott Furneaux, Barrister at Law, c/o T. H. Southerden, Esq., Box 1646 J.J., G.P.O., Sydney.
1914		Martin, A. H., Technical College, Sydney
1929	P 1	Matheson, Alexander James, Teacher, The High School, Dubbo.
1926		Mathews, Hamilton Bartlett, B.A. <i>Syd.</i> , Surveyor General of N.S.W., Department of Lands, Sydney.
1912		Meldrum, Henry John, B.A., B.Sc. 'Craig Roy,' Sydney Road, Manly.
1929		Mellor, David Paver, Assistant Lecturer in Inorganic Chemistry in the University of Sydney; p.r. Flat 8, 'Deanville,' Milson-road, Cremorne
1922		Mills, Arthur Edward, M.B., Ch.M., Dean of the Faculty of Medicine, Professor of Medicine in the University of Sydney; p.r. 143 Macquarie-street.
1928		Micheli, Louis Ivan, Ph.D., Colonial Sugar Refining Co., Pyrmont.
1926		Mitchell, Ernest Marklow, 106 Harrow Road, Rockdale.

## Elected.

- 1879 Moore, Frederick H., Union Club, Sydney.  
 1931 Moppett, Warnford, M.D., Ch.M., Cancer Research Department, University of Sydney.  
 1922 P 17 Morrison, Frank Richard, A.A.C.I., F.C.S., Assistant Chemist, Technological Museum, Sydney; p.r. Brae-st., Waverley.  
 1924 Morrison, Malcolm, Department of Mines, Sydney.  
 1879 Mullins, John Lane, M.L.C., M.A. Syd., 'Mount Stewart,' Edgecliff Road, Edgecliff.  
 1915 Murphy, R. K., Dr. Ing., Chem. Eng., Lecturer in Chemistry, Technical College, Sydney.  
 1923 P 2 Murray, Jack Keith, B.A., B.Sc. Agr., Principal, Queensland Agricultural College, Gatton, Queensland.
- 1893 P 4 Nangle, James, O.B.E., F.R.A.S., Superintendent of Technical Education, The Technical College, Sydney; Government Astronomer, The Observatory, Sydney. (President 1920.)  
 1930 P 1 Naylor, George Francis King, 'Kingsleigh,' Ingleburn, New South Wales.  
 1924 Nickoll, Harvey, L.R.C.P., L.R.C.S., Barham, via Mudgee, N.S.W.  
 1891 Noble, Edward George, L.S., 8 Louisa Road, Balmain.  
 1920 P 1 Noble, Robert Jackson, M.Sc., B.Sc. Agr., Ph.D., Biologist, Dept. of Agriculture, Box 36A, G.P.O., Sydney, p.r. 'Casa Loma,' Shell Cove Road, Neutral Bay. *Hon. Secretary.*
- 1903 ‡Old, Richard, 'Waverton,' Bay Road, North Sydney  
 1921 Olding, George Henry, 'Werriwee,' Wright's Road, Drummoyne.  
 1930 O'Leary William, S.J., Seismologist, St. Ignatius' College, Riverview, Sydney.  
 1913 Olle, A. D., F.C.S., 'Kareema,' Charlotte-street, Ashfield.  
 1928 Osborn, Theodore George Bentley, D.Sc., F.L.S., Professor of Botany in the University of Sydney.  
 1921 P 3 Osborne, George Davenport, D.Sc., Lecturer and Demonstrator in Geology in the University of Sydney.
- 1921 P 1 Parkes, Varney, Conjola, South Coast.  
 1928 Parsons, Stanley William Enos, Analyst and Inspector, N.S.W. Explosive Department, p.r. Shepherd Road, Artamon.  
 1920 P 57 Penfold, Arthur Ramon, F.C.S., Curator and Economic Chemist, Technological Museum, Harris-street, Ultimo.  
 1881 Poate, Frederick, F.R.A.S., L.S., 'Clanfield,' 50 Penkivil-street, Bondi.  
 1919 Poate, Hugh Raymond Guy, M.B., Ch.M. Syd., F.R.C.S. Eng., L.R.C.P. Lond., 225 Macquarie-street.  
 1896 Pope, Roland James, B.A., Syd., M.D., Ch.M., F.R.O.S. Edin., 185 Macquarie-street.  
 1921 P 2 Powell, Charles Wilfrid Roberts, A.I.C., c/o Colonial Sugar Refining Co., O'Connell-street  
 1918 Powell John, 17 Thurlow-street, Redfern.

## Elected

- 1927 Price, William Lindsay, B.E., B.Sc., 60 McIntosh-st., Gordon.  
 1918 Priestley, Henry, M.D., Ch M., B.Sc., Associate-Professor of  
 Physiology in the University of Sydney.  
 1893 Purser, Cecil, B.A., M.B., Ch M. *Syd.*, 185 Macquarie-street.  
 1929 Pyke, Henry George, Chemical Testing Assistant, N.S.W.  
 Government Tramways; p.r. Bellamy-street, Pennant  
 Hills.
- 1927 Radcliffe-Brown, Alfred Reginald, M.A., *Cantab.*, M.A., *Adel.*,  
 F.R.A.I., *Cantab.*, c/o. Institute for International Education,  
 2 West 45th Street, New York City, U.S.A.  
 1922 P 4 Raggatt, Harold George, B.Sc., "Meru," Epping-av., Epping.  
 1919 P 3 Ranslaud, Archibald Boscawen Boyd, B.Sc., B.E., Lecturer in  
 Physics, Teachers' College, The University, Sydney.  
 1931 Rayner, Jack Maxwell, Physicist to the Department of Mines,  
 Sydney; p.r. 125 William-street, Granville.  
 1928 Reidy, Eugene Nicholas, A.S.T.C., Analyst, Department of  
 Mines, Sydney.  
 1924 Robertson, James R. M., M.D., C.M., F.R.C.S., F.G.S., 'Vanduaara,'  
 Ellamang Avenue, Kirribilli.  
 1926 Ross, Allan Clunies, B.Sc., Colonial Mutual Building, 14  
 Martin Place, Sydney. (Member from 1915 to 1924.)  
 1884 P 1 Ross, Chisholm, M.D. *Syd.*, M.B., Ch M., *Edn.*, 225 Macquarie-st.  
 1895 Ross, Herbert E., Govt. Savings Bank Building, 14 Castle-  
 reagh-street, Sydney.  
 1925 Roughley, Theodore Cleveland, Zoologist, Technological  
 Museum, Sydney.  
 1929 Royle, Norman Dawson, M.D., Ch M. 185 Macquarie-street,  
 Sydney.  
 1907 Ryder, Charles Dudley, *D. Eng.* (Vienna), Assoc I.R.S.M., (L.),  
 Ass A.C.I., F.C.S., (L.), Public Analyst (by appoint.), "The  
 Astor," Macquarie-street, Sydney.
- 1922 Sandy, Harold Arthur Montague, 268 George-street.  
 1920 Sawyer, Basil, B.E., 'Birri Birra,' The Crescent, Vauchuse.  
 1920 Scammell, Rupert Boswood, B.Sc., *Syd.*, "Storrington," 10  
 Buena Vista Avenue, Clifton Gardens.  
 1919 Sear, Walter George Lane, c/o J. Kitchen & Sons, Ingles-st.,  
 Port Melbourne.  
 1923 P 1 Seddon, Herbert Robert, D.V.Sc., Director, Veterinary Research  
 Station, Glenfield.  
 1918 Sovier, Harry Brown, c/o Lewis Berger and Sons (Aust.) Ltd.,  
 Cathcart House, Castlereagh-street.  
 1924 Shelton, James Peel, M.Sc., B.Sc. Agri., Holland-av., Bellevue  
 Hill.  
 1927 Shearsby, Alfred James, 152 Bland-street, Haberfield.  
 1917 Sibley, Samuel Edward, Mount-street, Coogee.  
 1900 Simpson, R. C., Lecturer in Electrical Engineering, Technical  
 College, Sydney.  
 1922 P 1 Smith, Thomas Hodge, Australian Museum, Sydney.



**Elected**

1919		Southee, Ethelbert Ambrook, O.B.E., M.A., B.Sc., B.Sc. Agr., Principal, Hawkesbury Agricultural College, Richmond, N.S.W.
1921		Spencer-Watts, Arthur, 'Araboonoo,' Glebe-street, Randwick.
1917		Spruson, Wilfred Joseph, S.M. Herald Building, Pitt and Hunter-streets, Sydney.
1916		Stephen, Alfred Ernest, F.C.S., c/o Union Club, Bligh-street, Sydney
1921		Stephen, Henry Montague, B.A., LL.B., c/o Messrs. Maxwell and Boyd, 17 O'Connell-street.
1914		Stephens, Frederick G. N., F.R.C.S., M.B., Ch.M., Captain Piper's Road and New South Head Road, Vaucluse.
1920	P 1	Stephens, John Gower, M.B., Royal Prince Alfred Hospital, Camperdown.
1913		Stewart, Alex. Hay, B.E., 'Yunah,' 22 Murray-street, Croydon
1900	P 1	Stewart, J. Douglas, B.V.Sc., M.R.C.V.S., Professor of Veterinary Science in the University of Sydney; p.r. 'Berelle,' Homebush Road, Strathfield. <i>Vice-President</i> . (President 1927.)
1909		Stokes, Edward Sutherland, M.B. Syd., F.R.C.P. Del., Medical Officer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1916	P 1	Stone, W. G., Assistant Analyst, Department of Mines, Sydney.
1920		Sulman, Sir John, Kt., Warring-st, McMahon's Point, North Sydney.
1918		Sundstrom, Carl Gustaf, c/o Federal Match Co., Park Road, Alexandria.
1901	P 13	†Sussmilch, C. A., F.G.S., F.S.T.C., A.M.I.E.Aust., Principal of the East Sydney Technical College, and Assistant Superintendent of Technical Education. (President 1922). <i>Hon. Secretary</i> .
1919		†Sutherland, George Fife, A.R.C.Sc., Lond., Assistant-Professor in Mechanical Engineering, in the University of Sydney.
1920		Sutton, Harvey, O.B.E., M.D., D.P.H. <i>Melb</i> , B.S. <i>Oxon</i> . p.r. 'Lynton,' Kent Road, Rose Bay. Professor of Preventive Medicine and Director, Commonwealth Health Dept., University of Sydney.
1926		Tannahill, Robert William, B.Sc. Syd., M.Sc. "Eastwell," 40 Cammaray Avenue, North Sydney.
1915	P 3	Taylor, Harold B., D.Sc. Kenneth-street, Longueville.
1905		†Taylor, John M., M.A., LL.B. Syd., 'Woonona,' 43 East Crescent-street, McMahon's Point, North Sydney.
1923		Thomas, David, B.E., M.I.M.M., F.G.S., 15 Clifton Avenue, Burwood.
1919		Thorne, Harold Henry, B.A. <i>Canab.</i> , B.Sc. Syd., Lecturer in Mathematics in the University of Sydney; p.r. Rutledge-st., Eastwood.
1916		Tillyard, Robin John, M.A., D.Sc. F.R.S., F.L.S., F.E.S., Chief Commonwealth Entomologist, G.P.O., Box 109, Canberra, F.C.T.
1923		Tindale, Harold, Works Engineer, c/o Australian Gas-Light Co., Mortlake.
1923		Toppin, Richmond Douglas, A.I.C., Box 1454 J.J. G.P.O., Sydney
1879		Trebeck, P. C., c/o Box 367 F., G.P.O., Sydney; p.r. No. 4 Chesterton Flats, Cababella-street, Kirribilli.

Elected	
1925	Tye, Cyrus Willmott Oberon, Director of Development and of the Migration Agreement Executive Committee, Public Works Dept. Building, Sydney; p.r. 19 Muston-street, Mosman.
1890	Vicars, James, M.E., Memb. Intern. Assoc. Testing Materials; Memb. B. S. Guild; Challis House, Martin Place.
1921	Vicars, Robert, Marrickville Woollen Mills, Marrickville.
1892	Vickery, George B., 9th Floor, Barrack House, Barrack-street, Sydney.
1903	P 6 Vonwiller, Oscar U., B.Sc., F Inst P., Professor of Physics in the University of Sydney. <i>Vice-President</i> . (President 1930.)
1910	Walker, Charles, 'Lynwood,' Terry Road, Ryde.
1910	Walker, Harold Hutchison, Vickery's Chambers, 82 Pitt-st.
1879	Walker, H. O., 'Moora,' Crown-street, Granville.
1919	P 1 Walkom, Arthur Bache, D.Sc., Science House, Gloucester and Essex Streets.
1903	Walsh, Fred., J.P., Consul-General for Honduras in Australia and New Zealand; For. Memb. Inst. Patent Agents, London; Patent Attorney Regd. U.S.A; Memb. Patent Law Assoc., Washington; Regd. Patent Attorn. Comm. of Aust; Memb. Patent Attorney Exam. Board Aust; 4th Floor, 16 Barrack House, Barrack-street, Sydney; p.r. 'Walsholme,' Centennial Park, Sydney.
1901	Walton, R. H., F.C.S., 'Flinders,' Martin's Avenue, Bondi.
1913	P 4 Wardlaw, Hy. Sloane Halero, D.Sc. Syd., Lecturer and Demonstrator in Physiology in the University of Sydney.
1922	Wark, Blair Anderson, V.C., D.Sc.O., M.I.Q.C., c/o Thompson and Wark, T. & G. Building, Elizabeth-street; p.r. 'Braeside,' Zeta-street, Lane Cove, Sydney.
1921	‡ Waterhouse, G. Athol, D.Sc. B.E., F.E.S., 39 Stanhope Road, Killara.
1924	Waterhouse, Leslie Vickery, B.E. Syd., 6th Floor, Wingello House, Angel Place, Sydney.
1919	Waterhouse, Lionel Lawry, B.E. Syd., Lecturer and Demonstrator in Geology in the University of Sydney.
1919	P 3 Waterhouse, Walter L., M.C., D.Sc Agr., D.I.C., 'Hazelmere,' Chelmsford Avenue, Roseville.
1876	Watkins, John Leo, B.A. Cantab., M.A. Syd., University Club, Castlereagh-street; p.r. 169 Avoca-street, Randwick.
1910	Watson, James Frederick, M.B., Ch M., 'Midhurst,' Woollahra.
1911	P 1 Watt, Robert Dickie, M.A., B.Sc., Professor of Agriculture in the University of Sydney. (President, 1925). <i>Vice-President</i> .
1920	P 29 Welch, Marcus Baldwin, B.Sc., A.I.C., Economic Botanist, Technological Museum.
1920	P 1 Wellish, Edward Montague, M.A., Associate-Professor in Mathematics in the University of Sydney.
1921	Wenholz, Harold, B.Sc Agr., Director of Plant Breeding, Department of Agriculture, Sydney.

# XX.

## Elected

1881		† Wesley, W. H., London.
1931		Wheatley, Frederick William, Director of Education, Cranbrook School, Edgecliff.
1922		Whibley, Harry Clement, 39 Moore-street, Leichhardt.
1909	P 3	† White, Charles Josiah, B.Sc., Lecturer in Chemistry, Teacher's College.
1892	P 2	White, Harold Pogson, F.C.S., Assayer and Analyst, Department of Mines; p.r. 'Quantox,' Park Road, Auburn
1928		Wiesener, Frederick Abbey, M.B., Ch.M., D.O.M.S., 143 Macquarie-street, Sydney
1921		Willan, Thomas Lindsay, B.Sc.
1920		Williams, Harry, A.L.C., c/o Whiddon Bros.' Rosebery Lanelines Pty. Ltd, Arlington Mills, Botany.
1891		Wood, Percy Moore, L.R.C.P. Lond., M.R.C.S. Eng., 'Redcliffe, Liverpool Road, Ashfield.
1906	P 11	Woolnough, Walter George, D.Sc., F.G.S., 'Callabonna,' Park Avenue, Gordon (President, 1926)
1916		Wright, George, c/o Farmer & Company, Pitt-street.
1917		Wright, Gilbert, Lecturer and Demonstrator in Agricultural Chemistry in the University of Sydney.
1921		Yates, Guy Carrington, 184 Sussex-street.

## Elected

## HONORARY MEMBERS

*Limited to Twenty.*

M — Recipients of the Clarke Medal

- |      |  |
|------|--|
| 1914 | Hill, James P, DSC, FRS, Professor of Zoology, University College, London  |
| 1908 | Kennedy, Sir Alex B W, Kt, IL D, D EN, FRS, Emeritus Professor of Engineering in University College, London, 17 Victoria-street, Westminster, London S W |
| 1931 | Lyle, Sir Thomas Ranken, KB, CBE, MA, DSc, FRS, "Lisbuoy," Irving Road, Toorak, Melbourne  |
| 1915 | Maitland, Andrew Gibb, FGS, Ex-Government Geologist of Western Australia 'Bon Accord,' 28 Melville Terrace, South Perth, W A                             |
| 1912 | Martin, C J, CMG, DSC, FRS, Director of Animal Nutrition, CS and IR University of Adelaide   |
| 1930 | Masson, Sir David Orme, KBE, MA, DSc, IL D, 14 William-street, South Yarra, Victoria.  |
| 1926 | Smith, Grafton Elliott, MA, MD, FRS, FRCI, Professor of Anatomy in the University College, London  |
| 1915 | Thomson, Sir J J, OM, DSC, FRS, Nobel Laureate, Master of Trinity College, Cambridge, England  |
| 1921 | Threlfall, Sir Richard, CBE, MA, FRS, lately Professor of Physics in the University of Sydney, 'Oakhurst' Church Road, Edgbaston, Birmingham, England    |
| 1922 | Wilson, James T, MB, CM, Edn, FRS, Professor of Anatomy in the University of Cambridge, England 31 Gungie Road, Cambridge, England                       |

## OBITUARY 1931-32

*Ordinary Members.*

## Elected.

- 1922 Grant, Robert  
 1877 Hamlet, William Mogford  
 1914 Reid, David  
 1919 Stroud, Sydney Harnett

## AWARDS OF THE CLARKE MEDAL.

Established in memory of

The Revd. WILLIAM BRANWHITE CLARKE, M.A., F.R.S., F.G.S., etc.  
*Vice-President from 1866 to 1878.*

To be awarded from time to time for meritorious contributions to the Geology, Mineralogy, or Natural History of Australia. The prefix \* indicates the decease of the recipient.

Awarded

- 1878 \*Professor Sir Richard Owen, K.C.B., F.R.S.
- 1879 \*George Bentham, C.M.G., F.R.S.
- 1880 \*Professor Thos. Huxley, F.R.S.
- 1881 \*Professor F. M'Coy, F.R.S., F.G.S.
- 1882 \*Professor James Dwight Dana, LL.D.
- 1883 \*Baron Ferdinand von Mueller, K.C.M.G., M.D., Ph.D., F.R.S., F.L.S.
- 1884 \*Alfred R. C. Selwyn, LL.D., F.R.S., F.G.S.
- 1885 \*Sir Joseph Dalton Hooker, O.M., G.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S.
- 1886 \*Professor L. G. De Koninck, M.D.
- 1887 \*Sir James Hector, K.C.M.G., M.D., F.R.S.
- 1888 \*Rev. Julian E. Tenison-Woods, F.G.S., F.L.S.
- 1889 \*Robert Lewis John Ellery, F.R.S., F.R.A.S.
- 1890 \*George Bennett, M.D., F.R.C.S. Eng., F.L.S., F.Z.S.
- 1891 \*Captain Frederick Wollaston Hutton, F.R.S., F.G.S.
- 1892 \*Sir William Turner Thiselton Dyer, K.C.M.G., C.I.E., M.A., LL.D., Sc.D., F.R.S., F.L.S.
- 1893 \*Professor Ralph Tate, F.L.S., F.G.S.
- 1895 \*Robert Logan Jack, LL.D., F.G.S., F.R.G.S.
- 1896 \*Robert Etheridge, Jr.
- 1896 \*The Hon. Augustus Charles Gregory, C.M.G., F.R.G.S.
- 1900 \*Sir John Murray, K.C.B., LL.D., Sc.D., F.R.S.
- 1901 \*Edward John Eyre.
- 1902 \*F. Manson Bailey, C.M.G., F.L.S.
- 1903 \*Alfred William Howitt, D.Sc., F.G.S.
- 1907 Walter Howchin, F.G.S., University of Adelaide.
- 1909 Dr. Walter E. Roth, B.A., Pomeroon River, British Guiana, South America.
- 1912 \*W. H. Twelvetees, F.G.S.
- 1914 A. Smith Woodward, LL.D., F.R.S., Keeper of Geology, British Museum (Natural History) London.
- 1915 \*Professor W. A. Haswell, M.A., D.Sc., F.R.S.
- 1917 Professor Sir Edgeworth David, K.B.E., C.M.G., D.S.O., B.A., D.Sc., F.R.S., F.G.S., The University, Sydney.
- 1918 Leonard Rodway, C.M.G., Honorary Government Botanist, Hobart, Tasmania.
- 1920 \*Joseph Edmund Carne, F.G.S.
- 1921 \*Joseph James Fletcher, M.A., B.Sc.,  
Richard Thomas Baker, The Crescent, Cheltenham.
- 1923 \*Sir W. Baldwin Spencer, K.C.M.G., M.A., D.Sc., F.R.S.
- 1924 \*Joseph Henry Maiden, I.S.O., F.R.S., F.L.S., J.P.
- 1925 \*Charles Hedley, F.L.S.
- 1927 Andrew Gibb Maitland, F.G.S., "Bon Accord," 28 Melville Terrace, South Perth, W.A.
- 1928 Ernest C. Andrews, B.A., F.G.S., Government Geologist, Department of Mines Sydney.
- 1929 Ernest Willington Skeats, D.Sc., A.R.C.S., F.G.S., University of Melbourne, Carlton, Victoria.
- 1930 L. Keith Ward, B.A., B.Sc., D.Sc., Government Geologist, Geological Survey Office, Adelaide
- 1931 Robin John Tillyard, M.A., D.Sc., F.R.S., F.L.S., F.E.S., Chief Commonwealth Entomologist, Canberra, F.C.T.

## AWARDS OF THE SOCIETY'S MEDAL AND MONEY PRIZE.

*Money Prize of £25.*

Awarded.

1882 John Fraser, B.A., West Maitland, for paper entitled 'The Aborigines of New South Wales.'

1882 Andrew Ross, M.D., Molong, for paper entitled 'Influence of the Australian climate and pastures upon the growth of wool.'

*The Society's Bronze Medal and £25.*

1884 W. E. Abbott, Wingen, for paper entitled 'Water supply in the Interior of New South Wales.'

1886 S. H. Cox, F.G.S., F.C.S., Sydney, for paper entitled 'The Tin deposits of New South Wales.'

1887 Jonathan Seaver, F.G.S., Sydney, for paper entitled 'Origin and mode of occurrence of gold-bearing veins and of the associated Minerals.'

1888 Rev. J. E. Tenison-Woods, F.G.S., F.L.S., Sydney, for paper entitled 'The Anatomy and Life-history of Mollusca peculiar to Australia.'

1889 Thomas Whitelegge, F.R.M.S., Sydney, for paper entitled 'List of the Marine and Fresh-water Invertebrate Fauna of Port Jackson and Neighbourhood.'

1889 Rev. John Mathew, M.A., Coburg, Victoria, for paper entitled 'The Australian Aborigines.'

1891 Rev. J. Milne Curran, F.G.S., Sydney, for paper entitled 'The Microscopic Structure of Australian Rocks.'

1892 Alexander G. Hamilton, Public School, Mount Kembla, for paper entitled 'The effect which settlement in Australia has produced upon Indigenous Vegetation.'

1894 J. V. De Coque, Sydney, for paper entitled the 'Timbers of New South Wales.'

1894 R. H. Mathews, L.S., Parramatta, for paper entitled 'The Aboriginal Rock Carvings and Paintings in New South Wales.'

1895 C. J. Martin, D.Sc., M.B., F.R.S., Sydney, for paper entitled 'The physiological action of the venom of the Australian black snake (*Pseudechis porphyriacus*).'

1896 Rev. J. Milne Curran, Sydney, for paper entitled 'The occurrence of Precious Stones in New South Wales, with a description of the Deposits in which they are found.'

## AWARDS OF THE WALTER BURFITT PRIZE.

## MONEY AND MEDAL.

*Money Prize of £50.*

Established as the result of a generous gift to the Society by Dr. W. F. BURFITT, B.A., M.B., Ch.M., B.Sc., of Sydney. Awarded at intervals of three years to the worker in pure and applied science, resident in Australia or New Zealand, whose papers and other contributions published during the past three years are deemed of the highest scientific merit, account being taken only of investigations described for the first time, and carried out by the author mainly in these Dominions.

Awarded

1929 Norman Dawson Royle, M.D., Ch M., 185 Macquarie-st., Sydney.



# PRESIDENTIAL ADDRESS

By PROFESSOR O. U. VONWILLER, B.Sc., F.Inst.P.

*(Delivered to the Royal Society of New South Wales, May 6, 1931.)*

## PART I.

It is fitting that I should commence my address with a reference to three noteworthy features of to-night's meeting; it is the first meeting of the Royal Society in its new home, it is the five hundredth general meeting of the Society, and it marks the commencement of the seventy-fifth year of its existence as the Royal Society of New South Wales.

The scientific community of this state is to be congratulated in acquiring Science House, a single building in which we hope that soon nearly all the societies concerned with science and its applications will have their headquarters. The mutual advantages of the increased facilities for co-operation and consultation are obvious, and we may look confidently for increased interest and efficiency in our work, and added achievement and usefulness. I take this opportunity of expressing on behalf of our members grateful appreciation of the efforts of all those who have contributed towards the establishment of Science House.

The history of this movement starts at the annual meeting of the Royal Society of New South Wales on 7th May, 1890, when the retiring President, Professor A. L. Liversidge, in the Anniversary Address, said that it



had long been his desire to see the Society provided with more suitable accommodation. In fact, that what was wanted was a modest edition of Burlington House, Piccadilly, which had been built by the Imperial Government to lodge learned societies. He believed that if the building were carried out even as a commercial undertaking it would prove a very useful investment.

In 1895 vacant land adjoining the Society's house was purchased, Professors Liversidge and David acting for the Society, and additions to the House were completed the following year.

In 1905 the matter of providing a home for the various scientific societies was again discussed and referred to a committee which included Professor Liversidge and Messrs. T. H. Houghton, G. H. Knibbs, and J. H. Maiden. As a result of their labours the House was enlarged, and the Engineering Association of N.S.W. and the Institute of Architects rented rooms in it, being followed shortly after by the Institution of Surveyors and the Dental Association of N.S.W.

The question of new premises was raised in 1914, when negotiations were entered for the purchase of a site and plans for a commodious building were prepared by Messrs. Ross and Rowe. No definite steps were taken during the war, but in the years that followed the matter of enlarging the Society's House and of erecting a new building were frequently discussed and proposals connected with it were brought before the Society by Mr. T. H. Houghton in 1918 and by Mr. A. B. Hector in 1919.

In 1920 Mr. H. C. Kent was appointed Honorary Architect and he prepared plans for extensions to the Royal Society's House, which were carried out in part in 1922, when a number of other societies became tenants.

Among those who urged strongly the building of a Science House at about this time was His Excellency the Governor of New South Wales, Sir Walter Davidson.

Following the appointment of a committee of the Royal Society to report on the question of rebuilding, an invitation was sent in June, 1925, to the Linnean Society of New South Wales to appoint representatives to a joint committee, and in November, 1925, other societies were approached to ascertain which would give financial assistance in the movement. As a result there was formed an Executive Committee of representatives of the Royal Society, the Linnean Society, and the Institution of Engineers of Australia, consisting of Mr. R. H. Cambage, Drs. H. G. Chapman, A. B. Walkom, G. A. Waterhouse, Sir George Julius, and Mr. W. J. Newbiggin. This committee approached the Government in March, 1926, with a view to asking assistance in the shape of a site for the erection of Science House. After lengthy negotiation and inspection of many sites a letter was received from the Premier (Hon. J. T. Lang) on 28th July, 1927, stating that the land on which Science House has now been erected would be granted. This action was endorsed by the succeeding Government and the Science House (Grant) Act was passed on 16th June, 1928. Valuable assistance was given at this stage by Mr. C. W. Tye.

In the meantime the Society's house, 5 Elizabeth Street, was sold (October, 1927).

With the aid of the Institute of Architects, in 1928, arrangements were made for an architectural competition, the adjudicators being Messrs. Oakeshott, Joseland, and Berry. Their awards were: First prize, Messrs. Peddle, Thorp and Walker; second prize, Mr. L. C. McCredie; third prize, Mr. John Crust.

Some delay occurred owing to difficulty in obtaining agreement to the form of deed of grant of the land, but after many conferences with the Crown Solicitors the deed of grant was executed and the land made available in September, 1929. Tenders were called for the building of Science House, that of Mr. John Grant being accepted in December, 1929, an agreement in respect to partnership in the building between the Royal Society, the Linnean Society and the Institution of Engineers being signed in the same month. The land was handed over on 7th March, 1930, and the building commenced under the supervision of Mr. S. G. Thorp.

On 24th June, 1930, the foundation stone was laid by His Excellency Sir Philip Game, and to-morrow (7th May, 1931) His Excellency has consented to declare the building open.

That the Royal Society was able to take the share it has in the financial responsibility of the undertaking is due to the excellent management of its affairs, especially in recent years. In this connection we are particularly indebted to our Honorary Treasurer, Dr. H. G. Chapman, for the extraordinarily able way in which he has conducted the financial side of our Society. We are indebted to him, too, for the effective part he took in the negotiations before and after the granting of the site.

The partnership between the three societies made the undertaking possible, because of the greatly increased resources, but at the same time it introduced many great difficulties because of the different points of view on many vital questions. That these difficulties were overcome is due to the determination to achieve their objective on the part of the committee of management appointed by the three societies to co-operate with architect and builder

during the erection of the House and to conduct it when erected. Our gratitude is due to the members of that committee and especially to the representatives of this Society, Dr. H. G. Chapman and Mr. C. A. Susasmilch, who, in addition to acting on that committee, have been responsible for the work of installing the Society in its new home early this year.

For the efforts of those mentioned and of many others we owe our thanks. It is for us and our successors to justify those efforts by making the Royal Society of New South Wales worthy of its name, its history and its home.

That we can celebrate our five hundredth meeting and our seventy-fifth birthday is evidence that the Society has been of value to the community; otherwise it could not have lived so long. During its long life, the Society, which under other names has existed for a period much greater than seventy-five years, has enjoyed varying fortunes; to-day, in common with the rest of the country, it is experiencing difficulties of an abnormal kind. While we may hope that the advantages of our new situation will compensate some of these, I feel that the time has come when we must review our position in view of altered conditions, and, if necessary, make changes, perhaps radical changes, in our methods, if we are to maintain our position and extend our influence and usefulness.

Thirty-six years ago, during a year of bad times, our membership fell from 445 to 420. During the past year it has fallen from 324 to 307. When we consider the change in the population of New South Wales during this period, a bad state of affairs is suggested, though I wish at once to point out that the figures do not necessarily indicate a falling off in the interest in science or in the quality of the work done by our Society. During the

last generation there have been formed many new scientific societies of varying degrees of importance, and mostly of highly specialised interests; one inevitable result is a fall in our membership, especially in times like these.

It is, I think, a matter of the greatest importance that we should take steps to maintain and to improve the position our Society holds, not for the sentimental reasons which are real enough among the older among us, but because it is very necessary that, besides the various specialised bodies, there should be one like ours where workers of all branches may meet, may know one another, and learn of the work of one another.

The library of the Royal Society, now adequately displayed for the first time, gives one good reason for making a special effort to improve the position of the Society. It is one of the best scientific libraries in Australia, and is available to all qualified to use it, whether members are not. Its growth depends largely on exchanges with other institutions, and our success in establishing these must depend on the value and variety of the papers in our proceedings, while, of course, our ability to purchase new works is limited with our income.

A further reason for the existence of a truly representative and authoritative society is that it may well form a channel through which scientific workers may offer their assistance to the state and through which the state may ask such assistance. At present, from time to time individuals among us are asked for help in connection with special problems, but the possibilities of such help are not realised as much as they might be. A Royal Society such as one would like this to be might do much in showing the people and their representatives the possibilities, and the limitations, of scientific endeavour.

That we cannot do all this at present is due partly to our lack of numerical strength, but mainly because certain sections of science are not represented adequately among our members. I feel that we must take steps to add to our numbers many who are now unable to join us either because we exclude them or because of financial considerations. This means constitutional changes not lightly to be made and a further development of our existing machinery for promoting sections specialising in various branches.

The changes I have indicated must be made only after long consideration. That is one reason why no definite steps were taken last year; another is that the financial uncertainty accompanying the changed condition of the Society rendered it unwise to take any step likely to cause financial embarrassment even of a temporary nature.

These matters will, I trust, receive further consideration, and I hope that it will soon be possible to invite applications for membership, if not full, at least associate, from all with good scientific qualifications, with a subscription rate which will be within the reach of the junior and poorly-paid scientific worker.

For the suggestions made here I alone am responsible; though some of my views have been mentioned to members of the Council, that body has not been invited to discuss them and has not yet been asked to express an opinion on them.

The Annual Report shows that, in spite of adverse conditions, the meetings of the Society maintained the standard of past years in the quality and number of papers submitted, and in the attendance of members. Measures taken during the year to make the monthly meetings of greater general interest to members have had encouraging

results, and it is hoped that, guided by last year's experience, further improvement will take place in the coming year.

I record with pleasure that Mr. E. C. Andrews has been awarded the Lyell Medal by the London Geological Society.

The Maiden Memorial Pavilion was opened on 20th May, 1930, by His Excellency Sir William Cullen, Lieutenant-Governor of New South Wales.

This year, the first Liversidge Memorial Lecture under the auspices of this Society will be delivered.

#### OBITUARY.

CHARLES CHILTON, M.A., D.Sc., M.B., Ch.M., was born in England in 1860 and was taken to New Zealand as a child. In Canterbury College he studied natural science and graduated with honours in zoology. After spending fifteen years as a schoolmaster with marked success, he left New Zealand and entered as a medical student at Edinburgh, where he had a distinguished course, followed by post-graduate work on diseases of the eye in England and the Continent. Returning to New Zealand, he practised in Christchurch as an ophthalmic surgeon, but at the same time devoted all his spare time to Zoology, publishing a series of important papers on the *Crustacea*. When Professor Dendy went to King's College, London, Dr. Chilton, who was acting professor in his absence, was appointed to the chair of biology at Christchurch.

He made a mark both as teacher and research worker, and also as administrator. Most of his published papers refer to the *Crustacea*, in which group he specialised. He

gave a good deal of attention to the fauna of subterranean waters and published a valuable memoir on the subterranean crustacea of New Zealand. In 1907 he took part in an expedition to the sub-Antarctic islands of New Zealand, and afterwards edited the volumes recording the scientific results. He was responsible for the establishment of the mountain biological station at Cass for the investigation of New Zealand alpine fauna and flora.

Professor Chilton, who was elected an honorary member of the Royal Society of New South Wales in 1918, became rector of Canterbury College in 1921, which position he held until 1927, when ill-health forced him to resign. He died on 25th October, 1929.

SIR WILLIAM TURNER THISTLETON-DYER, K.C.M.G. C.I.E., M.A., LL.D., Sc.D., F.R.S., was born in London in 1843. In 1861 he entered King's College with a view to qualifying in Medicine, but before completing his course, entered at Christchurch, Oxford, and graduated there in mathematics. At Oxford he became a keen student of botany, and, after leaving, occupied chairs in natural history and botany in quick succession at Cirencester, Dublin, and London. In London he came into touch with Sir James Hooker, Director at Kew, who had him appointed Assistant Director in 1875. At this period, with Huxley at the Royal College of Science, Thistleton-Dyer developed practical courses in botany—then for the first time a laboratory subject—his work being practically the starting-point of the modern scientific treatment of botany in Great Britain.

At Kew he realised the possibilities of the imperial function of the institution and kept the various botanical establishments of the Empire in close touch with it, stimulating everywhere botanical exploration and collec-



tion and the exchange and cultivation of useful plants. In 1885 he succeeded Hooker in the directorship, occupying this position until he retired in 1905. He was elected an honorary member of the Royal Society of New South Wales in 1900. After his retirement he devoted himself to the pursuit of classical studies and wrote several critical papers on the subject of plant names in the classics. He died on 28th December, 1928.

JOSEPH ELDRED BISHOP was born in Victoria in 1864 and came to Sydney as a newspaper representative in 1892. Later he became, in succession, secretary, manager and proprietor of West's Wheel Works and occupied a prominent place in a number of business associations and in various local movements. Elected a member of the Royal Society of New South Wales in 1920, he was a regular attendant at meetings, and in 1921 became chairman of the Industrial Section. He was actively interested in social, economic and political questions, and was a contributor to the Economics Section of the Australasian Association for the Advancement of Science, being also the writer of numerous articles in the press. He was a foundation member and Vice-President of the Economic Society of New South Wales. His death took place on 1st May, 1930.

ROBERT LIONEL FAITHFULL, L.R.C.P., M.D., New York, U.S.A., London, was a member of one of the oldest families in the State. He was a son of the late William Pitt Faithfull and was born on 27th July, 1853. He studied Medicine in Sydney and in the United States. For more than thirty years he practised in Sydney, and during late years occupied a prominent place in business affairs, being director of a number of important commercial institutions.

A man of quiet disposition, he enjoyed the high respect of his colleagues. He became a member of this Society in 1887, and though in recent years he seldom attended meetings, he retained his interest in its activities. He died at Moss Vale on 8th June, 1930.

JOSEPH PALMER was born in London in 1841 and came to Australia with his parents in 1853. After serving as clerk to Mr. Josiah Mullen, a sharebroker, for nine years, he commenced business on his own account in 1872 and was one of the first members of the then newly-formed Sydney Stock Exchange, of which he was at one time chairman. From boyhood he was keenly interested in religious matters and was an active worker in connection with the New South Wales Bush Missionary Society, the Y.M.C.A., and the Baptist Church. He published several books and many pamphlets on religious questions which received considerable attention. He was elected a member of this Society in 1880 and for a long time took an active interest in its proceedings. His death occurred on 7th May, 1930.

JOSEPH THOMPSON, M.A., LL.B., was born in Sydney 84 years ago. He attended the Sydney Grammar School (his name is the first on the list of pupils of that school), and, proceeding to the University of Sydney, graduated there as M.A. and LL.B. He read with the late Sir Edmund Barton and was admitted as a solicitor in December, 1871. He worked at his profession to within a few days of his death, and was one of the oldest solicitors practising in Sydney. He became a member of this Society in 1913. His death occurred on 28th October, 1930.

Before passing to the second part of my address, I wish to make further brief reference to the question of what part the scientist should take in the present state of

national and world affairs, and in particular to the suggestion, made in more quarters than one, that this is no time for investigations in pure science for its own sake, but that we should concentrate our efforts on solving the acute practical problems of the day. This view is illustrated by a cable message appearing in our press at the time of the last meeting of the British Association for the Advancement of Science. It was:

There are no outstanding papers. Indeed, many of the papers seem particularly futile in view of the gravity of the times in which men live. The minds of scientists are apparently not concentrated on the larger issues.

A young Cambridge professor propounded a new theory of the atom, which the scientists present confessed they were unable to understand. The author declined to put his theory in more simple language for fear of being inaccurate.

—"Sydney Morning Herald," 10th September, 1930.

I would point out that the criticism in this cable is not constructive; it does not indicate clearly what work the scientists should do in place of carrying out those investigations for which, presumably, they were well qualified. That chemists and physicists should try to devise schemes for the economic conduct of the country would hardly be profitable; their suggestions would probably be nearly as crude and futile as those so freely produced in parliament and press these days. In particular what should this young Cambridge professor do? Perhaps if he devoted himself to industry he might prove a brilliant success and invent labour-saving methods, with the immediate result of increasing greatly the number of unemployed; on the other hand, his achievement in such a field might well be negligible.

During the war, men of science proved themselves as adaptable and resourceful in invention as they had been

in research. Eminent chemists, mathematicians, physicists, geologists, biologists, worked on definite problems. and, thanks to their experience and training and to the unstinted expenditure on necessary equipment and apparatus, they achieved brilliant success in many instances; but to-day, unless problems are submitted for which the scientist's training specially equips him, and unless the necessary material assistance is provided for the attack on these problems, I do not see that he can do better than devote himself to that pursuit of knowledge which is the life of the true scientist and, incidentally, the foundation of all the advances which have benefited mankind in the past. The only futility I can see in the action of the Cambridge professor is the verbal delivery of a paper on a subject of extraordinary difficulty, understanding of which can come only after repeated reading and close study of the printed account. In a year in which centenaries connected with Michael Faraday and with Clerk Maxwell are celebrated it should be unnecessary to attempt to justify the pursuit of knowledge for its own sake.

While maintaining that all encouragement should be given to pure research, I can quite consistently urge that the State should use trained scientists to a greater extent in solving the many problems for which their knowledge and training equip them; that we should, on the one hand, try to let the scientist realise that he can assist in some of these, and, on the other, make our men of affairs understand what the scientist might do, given adequate time and material. As I stated earlier, a society such as ours might do particularly valuable work in imparting this knowledge of what is wanted and of what might be done.

## PART II.

## A GENERATION OF ELECTRON THEORY.

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Introduction.

In the second part of my address I feel that no apology is needed for a discussion of points of purely scientific interest. The selection of subject was suggested by an examination of past presidential addresses in which, for one delivered by a physicist, I had to go back thirty-six years to 1st May, 1895, when Professor Threlfall (now Sir Richard Threlfall) gave the anniversary address of this society. The perusal of that address reminds one at once of the vast increase in knowledge in physics gained since that day, and, at the same time, of the yet more remarkable changes in the attitude or viewpoint of the physicist. In that address a tribute is paid to three eminent German physicists who died not long before—Helmholtz, Hertz and Kundt. The recollection of the work of these men, together with the account of contemporary physical research given in that address, including a discussion on many investigations on electric oscillations and waves following the work of Hertz, reference to the beautiful application of wave theory of light to colour photography by Lippman and by Wiener, to much work on exact measurement of electrical properties of materials, and, as the crowning item, the discovery of argon by the late Lord Rayleigh, makes us realise that the curtain had not yet risen on what Lord Rutherford calls the heroic age of physics, the beginning of this generation of tremendous and sensational advance of knowledge and ideas.

The following quotation from that address, referring to the discovery of argon, is of interest, the first part indicating the knowledge and attitude of that time, while

the last part shows an appreciation of facts of which we might well be reminded to-day:—

“It appears to be a singularly inert gas, (to which property it owes its late discovery), heavier than nitrogen, and most probably an element, since there is strong evidence that it is monatomic. Should this be the case, room will have to be made for it in Mendelejeffs’ series,—one can only pray that it may fit a vacant place and not turn the whole of chemistry upside down by refusing to come in under the periodic law. It would come in if its atomic weight were twenty, but the discoverers think it is forty. However, out of such catastrophes, advances are apt to be made, and if we have to mend our periodic law we shall probably get something better in its place, perhaps some light on the dynamics underlying it. I cannot close this brief notice without directing your attention to the magnificent triumph which this discovery has obtained for the method of enquiry by means of prolonged, laborious, and exact measurement, as opposed to the method of happy inspiration. Contrary to the popular idea, the vast majority of discoveries have been made by the methods employed by Lord Rayleigh, of which the essence is that no obscurity, however small, is to be passed over until it is completely sifted.”

That address, however, was given only just before the first announcements of the remarkable discoveries which introduced the new era. Within a few months Röntgen discovered X-rays; in the following year Becquerel published an account of the first observations of radio-activity, while already J. J. Thomson and his students were engaged in the researches which, during the years immediately following, gave fundamental facts concerning the electron. During the next generation, as all know, we have had a succession of remarkable discoveries and an extraordinary growth of knowledge concerning atoms and atomic processes. With all the newly-discovered phenomena relating to atomic structure, electricity and light, we find electrons intimately associated, and all the new hypotheses and theories are closely bound with views as to the nature and behaviour of electrons, so that, as the last physics

address before this society was delivered just before the discovery of the electron, it seemed appropriate that in this one, given a generation later, I should review some phases of the advances in knowledge and changes in ideas following from that discovery.

Remarkable as have been the discoveries made during the last thirty-six years, I think that their significance in the history of physics will depend most of all on the extraordinary developments in the philosophy of the physicist, in the changes which have taken place in our statement of the fundamental principles in terms of which we describe the phenomena of nature, and it is to some of those that I wish particularly to address myself.

Thirty-six years ago certain fundamental principles were apparently completely and convincingly established. Newtonian mechanics, Maxwell's theory, and the principle of conservation of energy formed a foundation concerning which generally there were no doubts. In optics the idea of waves in an aether seemed adequately and uniquely to meet all the evidence, and Hertz's experiments had confirmed Maxwell's views as to these light waves being electric waves. Additional generalisations such as the second law of thermodynamics helped to give a generally satisfactory picture. Of course, there were innumerable difficulties and perplexities, and the physicists of that day were under no illusions as to the approaching completeness of their knowledge, but in general it was felt that future experiments and discovery would give solutions to these in terms of developments of the accepted theories, involving no radical changes in underlying ideas.

The outstanding feature in the philosophy of the physicist of that period was, perhaps, the deterministic outlook. Generally it was tacitly believed that a sufficiently

full knowledge of the universe was conceivable to enable a being with adequate mathematical skill to predict the course of events in the future, and to recall the past. Such knowledge would involve a statement of the position and momentum of each particle of matter at a given instant, and of the various physical laws describing the phenomena of nature. While it was recognised that we could never attain absolute accuracy of measurement, so that the necessary knowledge could not be obtained, the success which the physicist met in his constant endeavour to improve his measuring devices and his skill in using them, in his aspirations towards the extra place of decimals, which is one of the most important factors in the growth of knowledge, encouraged the belief that the future would lead to ever closer and closer approximation to absolutely precise determinations, and that with this we should be able more and more correctly to give the history, past and future, of each body in the universe.

The arguments of the philosophers who made suggestions that this was fundamentally wrong, that there was doubt as to the correctness of the accepted principles of the physicist, were esoteric; physicists, even the most eminent, generally were not in the inner circle which heard and understood these.

With the growth of our knowledge of atomic physics it has been necessary from time to time to introduce novel general principles, supplementing those hitherto sufficient, and later modifying some of these so that they are only special cases of greater generalisations, while during recent years there have taken place changes of a more profound nature, especially in connection with the deterministic view, the significance of which it is difficult to-day to assess, though there can be no doubt as to their importance and interest to both philosopher and physicist.



### The Beginning of Electron Theory.

The idea of a fundamental electric charge, an "atom of electricity," is quite old. The atomic theory of Dalton, combined with Faraday's laws of electrolysis, indicates clearly the existence of such unit charge, and the name "electron" was suggested for this hypothetical electric atom by Johnston Stoney some years before its isolation. The early history is well known; electrons separated from atoms were found in connection with electric discharge in gases, radio-activity, the photo-electric effect, emission from incandescent solids, all with the same charge and the same mass, while the Zeeman effect was interpreted to mean that within atoms there were also electrons of the same nature. The assumption that the mass was wholly electrical in nature, borne out by the discovery that the mass was not constant but depended on the velocity, led to an estimate of the actual size of the electron, which, for a long time, was visualised as a tiny sphere of negative electricity of quite definite size, though there were suggestions of it being a disc or a ring.

There can be no question as to the sensational character of the discovery, within a few years, of X-rays, radio-activity and the electron. Light was at once thrown on diverse phenomena in physics and chemistry, and many facts concerned with heat, light, elasticity, electricity, magnetism, chemical combination, the periodic law, were reconciled, at least qualitatively, with the new electron views. At the same time, while a new world of investigation was opened, at first there was no reason to suggest anything fundamentally wrong in the accepted bases of physics; it was generally felt that all the new and varied phenomena would be found eventually to fit in with the then accepted principles, though it is true that there were those who insisted that laws based exclusively on observations on

matter on relatively large scale must not be considered necessarily to hold when dealing with particles of atomic or sub-atomic dimensions.

In the theory of relativity, which in its simplest and special form was enunciated early in this century, and in Planck's quantum theory, advanced to reconcile the facts of full radiation at about the same time, we have the first suggestions of radical changes in accepted views; but both these theories, especially the latter, did not receive general attention when first stated, several years elapsing before their significance was realised. One of the earliest applications of the theory of relativity was to the question of the relation between mass and velocity of an electron; the close agreement between prediction and observation was a triumph for the theory and at the same time strengthened the view that the picture formed of the electron was essentially correct.

#### **Theories of X-rays.**

An interesting phase in the development of our ideas is the controversy regarding the nature of X-rays in the early years of this century. Though apparently ended in 1912, it is, I think, worthy of notice in view of recent developments. Practically from the time of their discovery the commonly accepted view of X-rays was that they were a kind of light of very short wave-length, though for a long time there was no convincing proof of this. Undoubtedly there were difficulties in the wave theory, and Sir J. J. Thomson at quite an early stage made what appeared a far-fetched and rather unconvincing picture of the "spotted wave front" to remove these. This is notable because he introduced the idea of the energy being localised at certain points on the wave front instead of being distributed continuously as in the then accepted view of light waves.

Based on a study of the secondary effects produced by X-rays, Sir William Bragg advanced an alternative theory which, though put on one side after a few years, attracted a lot of attention at the time and is interesting to-day because it involved certain ideas greatly resembling those now accepted. This was the neutral pair theory, according to which X-rays consisted of a doublet, a negative and a positive electron, the latter having a negligible mass. The interaction between matter and such a doublet might result in the detachment of the positive, the negative going off as a free electron with the same energy as the original doublet; this free electron, meeting matter again, might pick up a positive, an X-ray similar to the original one being so produced. Bragg showed that the various phenomena of X-rays, their great penetrating power, absence of deflection in magnetic and electric fields, polarisation on reflection, secondary effects, all fitted in with his theory, at least as well as with the wave theory. It is interesting to see how each experimental fact advanced to disprove his theory was shown by him to be consistent with it and, in a number of cases, to favour it against the other.

In 1912 the discovery of diffraction effects of X-rays seemed definitely to settle the question; at least it showed that X-rays were light rays, and, as is well known, Bragg himself developed this line of attack, becoming the recognised leader in using interference effects with X-rays as a means of investigating the arrangement of atoms in crystals. We have to remember that the generally accepted view of light in 1912 is by no means the same as that of the present day, and while Bragg's hypothesis then seemed quite wrong, it actually has important features in common with those of to-day. The idea of the change from one form to another, X-ray to electron to X-ray, the energy being constant, we accept to-day though we do not admit

his picture of the X-ray—not that we have any picture to substitute for it. Of course, one important point of divergence is that on his view the speed of the X-ray is less than that of light. A particularly interesting point to recall is the admission that there must be a wave associated with the formation of the X-ray, there being produced together the doublet and an aether wave, the latter being of negligible energy. This suggestion of duality, corpuscle and wave, is notable when we consider the present-day views. One point in particular we might note here, one illustrated time after time, namely, that more than one picture might be made to fit the observations; that we can form only one picture consistent with all the known facts is no proof that it is correct. This is not a new idea; many years ago Clerk Maxwell pointed out that an infinity of hidden mechanisms can be imagined, all of which will produce a given motion of the observable parts of a dynamical system; but I think that the appreciation of this is far more general to-day than even a few years ago. One important difference in the attitudes of the physicist of to-day and of the past is in the picture made of physical processes; to-day such a picture possesses no value except its convenience; it may afford a suitable method of stating the laws of some phenomenon, simpler than or supplementing, mathematical expression, and suggesting further developments. Often in the past such pictures were regarded as very real presentments.

By 1912 Planck's quantum hypothesis had gained ground, receiving support through its application to the question of the variation with temperature of specific heats and particularly through Einstein showing that the facts of photo-electricity were quantitatively consistent with it; these facts seemed definitely to show that the energy in

light waves was localised, not distributed in a continuous manner over the wave surface, and so introduced the outstanding difficulty of modern physics, the double nature of light, sometimes apparently inevitably undulatory, at others equally inevitably corpuscular. At this time there was not a general realisation of the fact that the quantum theory, applied to X-rays and  $\gamma$ -rays, would reconcile the various facts of the secondary effects of these radiations, otherwise the decision that they were of the same nature as light might have been made earlier. That it was not, is, however, not surprising, because at the time only those aspects of X-rays demanding a corpuscular interpretation were prominent; it was after diffraction effects were noted that the same duality and the same difficulties were found with both light and X-rays.

In 1913 the wave theory of X-rays was well established, or rather the fact that many phenomena connected with X-rays as with light seemed to demand a wave theory, and the work of Rutherford on scattering of  $\alpha$  particles and that of Moseley on characteristic X-rays established the nuclear theory of the atom, giving a picture of the counterpart of the electron, the proton, an entity with positive charge equal to the negative charge on the electron, a mass about 1840 times as great and a radius as many times smaller if classical theory could be applied to such cases. Moseley's work, it will be remembered, established the importance of the atomic number, solving the difficulty of the atomic weight of argon being 40—the "catastrophe" of 1895.

#### **The Bohr Atom.**

In this year came one of the most notable advances, Bohr's theory of the hydrogen atom, giving a picture of the atom and a statement of the processes of light emission consistent to the highest precision obtainable with the

observed facts of the spectrum of atomic hydrogen, a theory notable because it introduced new extensions, limitations, and qualifications to the classical electro-magnetic theory, namely, the restriction of the electronic orbits, possible on the old theory, to these satisfying certain quantum conditions, and the assumption that an electron in such orbit is non-radiating, whereas on the classical theory it must radiate energy. The essential point of this theory, of course, is the idea that the emission of light accompanies the transition from one of these "stationary states" to another, the frequency of the light being proportional to the change in energy of the atom in accordance with Planck's quantum hypothesis,  $W = h\nu$ .

The Bohr theory thus introduces new concepts not to be expected from classical theory and in fact at variance from it, though at the same time the picture of the atom is based on classical considerations.

A specially significant feature is the lack of definiteness of statement of the behaviour of an individual atom. For example, if a hydrogen atom is in a state other than those of lowest or second lowest energy, one of a number of transitions might occur. To take a special case: if it is in a state characterised by principal quantum number 5, it might change to any one of states 4, 3, 2, or 1, with the emission of the corresponding light quantum. It may be possible to determine the relative probabilities of the occurrence of these changes so that if we are concerned with a large number,—say a million—of such atoms, the numbers making each of the four possible changes might be predicted and therefore the relative intensities of the four spectral lines; in other words, we have statistical knowledge and can give statistical laws, but concerning the individual atom all that can be given is a statement of the

various changes possible and their relative probabilities. For any so excited atom these probabilities of making spontaneously given changes might be modified by various factors as the presence of fields of force, of radiation of various kinds, but it appears impossible to determine which of several possible changes actually is to take place. This constitutes an important departure from the deterministic view; instead of predicting what will happen, statement can be made only of possible happenings and of the relative probabilities of their occurrence. Of course, it is not obvious that this interpretation must be put on Bohr's theory, but the strong suggestion of indetermination is interesting, inasmuch as it leaves room for the introduction of influences other than those accounted for by the ordinary physical laws, call it the law of chance, divine control, or what you will.

Developed brilliantly by Bohr and many others, the theory achieved remarkable success, which is now common knowledge. The observed facts of the spectra of many elements fitted it, new effects such as the multiplicity of the hydrogen lines were predicted and verified in striking manner. For ten years the theory was accepted as giving a picture of atoms essentially correct, that there are stationary non-radiating states characterised by definite electronic orbits, a spectral line corresponding with the transition from one such state to another, the transition involving an electron changing from one orbit to another or perhaps two or more electrons making such changes simultaneously. The X-ray spectra supported the theory convincingly, while Bohr showed that the facts of the periodic law were well explained with the aid of Pauli's principle that no two electrons in an atom can have the same set of quantum numbers.

The difficulties certainly were great. In the first place, while more or less definite pictures were given of the various stationary states of atoms, it was impossible to visualise the process of transition or to see why and how it should be accompanied by the emission of light of the frequency indicated by Planck's law. Then, while there were many cases of excellent agreement between observation and theory, there were noteworthy inconsistencies; to reconcile some of the frequency relations between certain spectral lines it was necessary to introduce arbitrary modifications and corrections to the quantum numbers such as the addition or subtraction of  $1/2$ , justified often only by their success. It is true that the idea of electron spin helped a lot in connection with the Zeeman effect and multiplicities of lines in certain optical and X-ray spectra, giving in fact remarkable quantitative agreement in many cases, but with wider application the Bohr theory had to be modified more and more seriously, losing the attraction of its original simplicity in the endeavour to make it meet the ever-increasing observations. This has been the fate of many theories in the past; at first a simple statement is adequate, but with attempts to prove its general application it has ever to be made more and more complicated until it is so cumbersome that it breaks down. One recalls Newton's corpuscular theory of light, adequate for the facts of reflection and refraction; the endeavour to reconcile with it what we now call interference effects involved complications such as the introduction of periodicity, giving an air of artificiality which, with the work of Young and Fresnel more than one hundred years later, led to it being discarded, though to-day we can see in it a suggestion of the twofold nature of light which now we are compelled to accept.



That twofold nature of light was emphasised more than ever by Bohr's theory, which gives a picture fitting remarkably well one class of light phenomena, those involving the corpuscular idea, but a picture impossible to reconcile with interference and diffraction effects. It is true that his correspondence principle showed certain approximations between deductions from the classical and the later theory, but this in no way removed the difficulties. More and more clearly was it established that, while the theory of Bohr gave a remarkably accurate method of statement, one consistent with many observational facts and valuable as a means of prediction of new knowledge, its extended success depended on so many and such artificial modifications that it was quite obvious that it was incapable of satisfying all demands made on it, that many phenomena concerning spectra would not fit the theory. No one was more emphatic on this point than Bohr himself, who has taken a prominent part in developing the later ideas now to be discussed.

#### Wave Mechanics.

The latest stage in our theories commences with de Broglie's postulate of electron waves enunciated seven years ago. There had already been a number of suggestions that the association of an internal frequency with the individual electron would remove certain difficulties in the interpretation of spectra, and the idea of the spinning electron advanced somewhat later was a quantitative application of this used with remarkable success in amplifying the original Bohr theory. De Broglie, by logical development of the ideas of Einstein and Planck, showed that, associated with an electron (and, in fact, with any particle), there should be a frequency proportional to the mass and depending on the velocity, and waves of some kind, the wave length also depending on mass and velocity.

In the case of electrons with velocities met in ordinary observations, the wave lengths calculated are comparable with those of X-rays. On de Broglie's theory the wave is a guide or control of the particle; the changes of motion of an electron are due to modifications of the wave motion, refraction for example, wave mechanics being thus introduced instead of the Newtonian mechanics. Extended mathematically by Schrödinger and others, this wave theory has proved extremely fruitful, producing excellent agreement between theory and observation, and in general bringing order into the almost chaotic hypotheses of atomic behaviour. It introduces many difficulties: the first is the question of the nature of these waves. They are not light waves; their velocity is greater than that of light, being as many times greater than it as the velocity of the particle is less—this being itself a startling view when we recall the impression formed from relativity considerations of the impossibility of a velocity equalling, let alone exceeding, that of light. Then the mechanism by which such rapidly travelling waves guide slowly-moving particles is not easy to visualise. The position is not simplified by the later developments of Schrödinger and others, indicating that generally the waves are not three dimensional but multi-dimensional.

The first difficulty is met by the fact that in a case of wave motion in which the wave velocity depends on the frequency, as it does in the de Broglie waves, the velocity of transport of energy is the group velocity and not the wave velocity. In the case of de Broglie waves the group velocity is readily shown to be the velocity of the particle. De Broglie visualised the electron, associated with which is all the energy, as the centre of a wave group moving with it, modifications of the waves causing changes in the motion of the electron.

This theory does not remove the old difficulty of duality in the phenomena of light; instead it extends it, making it a general principle. At first this duality was met in light in the visible and ultra-violet, then it was apparent in X-rays and  $\gamma$ -rays, and now we have in the electron, and presumably in all matter, in addition to the well-known corpuscular attributes, wave characteristics, though the waves must be essentially different in nature from light waves. In the suggestion that the motion of matter is really controlled by the waves, that to describe it we must formulate the laws of these waves and determine their behaviour, in place of the ordinary method of Newton's laws of motion, we have an absolutely novel idea. Of course, in the case of particles of ordinary matter the waves are extremely short, and it can be shown that here the Newtonian laws give correct results; in the case of electrons the new theory often gives results very different from those of the old theory and, as already stated, more consistent with observed facts.

Applied to the hydrogen atom these new waves fitted well with the stationary states, the orbits of Bohr being orbits which satisfied the condition that stationary matter waves of wave length appropriate to the electron speed in the orbit could be established. For example, in the case of circular orbits in which the electron speed is constant, the orbits must have a length equal to an integral number of wave lengths; the orbits satisfying this "resonance" idea are found to agree excellently with those calculated by Bohr.

The most striking evidence is given by the discovery that with a stream of electrons diffraction or interference effects can be obtained resembling those of  $\gamma$ -rays. Practically all the experiments on reflection and transmission

of X-rays with crystals can be repeated with electrons with similar results. A beam of electrons falling on a crystal is reflected as a number of beams in various definite directions, depending on the grating constant of the crystal, on the angle of incidence and on the speed of the electrons, and the wave lengths indicated by such experiments depend on the velocity exactly as the theory demands. This experiment corresponds with those of Bragg with X-rays; other experiments on the transmission through thin sheets of crystalline matter give patterns suggesting those obtained by Laue with X-rays. Further, just as a ruled diffraction grating has been used in X-ray analysis, so it has with a stream of electrons.

Such results as these might well be taken as affording overwhelming evidence of the objective reality of the waves and of the correctness of the view that they do guide the electrons. However, we must exercise caution in coming to this decision. Here again in the endeavour to make the theory fit in with all the pertinent facts, there has been introduced a succession of extensions and modifications of the original de Broglie idea, each fresh hypothesis in turn having to be discarded or further modified.

At one time the old idea of the electron was abandoned altogether; it was thought that it was the wave group and not what is equivalent to a point in it, that instead of being a tiny particle it had practically infinite extension; but the density of charge being measured by the intensity of the wave, the effective volume was actually very small, but still much greater than that formerly attributed to the electron.

A later idea is that the electron might be as originally visualised, but that from the wave function giving the wave amplitude at each point of space an estimate is

obtained, giving not the actual density of charge there but the probability of the electron being at that point, the chance of the electron being in any particular position being proportional to the wave intensity there.

We have in this last idea, which with important modifications is widely favoured at present, an extension of that notion of indefiniteness already indicated in Bohr's first work. We do not picture the electron in a definite position, but simply state the probability of its being in any place, maintaining that it is possible for it to be elsewhere.

This apparent retrograde step, however, leads to progress, one important achievement being the application of like ideas to  $\alpha$  particles, the well-known relation between stability of radio-active atoms and speed of emission of  $\alpha$  particles, the Geiger-Nuttall law, being in excellent accord with the demands of this theory.

There are many other triumphs of these new theories; the later difficulties of the original Bohr theory are removed, the facts of the Zeeman effect, the Raman effect are consistent with it, remarkable results such as the existence of two kinds of hydrogen molecule are predicted and verified by absolutely independent methods, good progress is made in obtaining expressions for the relative intensities of lines in spectra, though much remains to be done here both from theoretical and experimental standpoint. One interesting application is indicated which may prove of great value. Electron diffraction gives a method of examining the thin films of gas existing on metal surfaces. Further knowledge of these will undoubtedly assist in the solution of many problems in physical chemistry of scientific and economic importance. However, instead of discussing these, I wish rather to point out some more striking consequences of these latest views.

### The Uncertainty or Indetermination Principle.

Perhaps the change in our ideas, fundamentally most important, is that involved in the principle of uncertainty or indetermination enunciated by Heisenberg in 1927, and now widely accepted as an inevitable truth. To appreciate its significance we must recall the deterministic view of a generation ago. Already we have seen that modern theory indicates that when we consider atoms and their constituents we cannot hope to make definite predictions concerning the individual, but that we may try to determine a number of possible changes and the relative chances of the occurrence of these. We have seen, too, that the latest work shows often an indefiniteness in the statement of the position of a particle, that we may be able to say, not where a particle is, but what is the chance of its being at a given point at some particular moment. The principle of indetermination states that both the position and the momentum of a particle cannot be determined with absolute accuracy, that from the nature of things there must be an error or uncertainty in the measurement of one or both these quantities, and further, that the product of the two amounts of uncertainty cannot be less than a definite though small amount, namely,  $h/2\pi$ . The greater the precision with which one quantity is measured, the greater the inevitable uncertainty in the other. If, for example, the position of an electron could be determined with absolute certainty, the velocity must be absolutely indefinite and *vice versa*. Many examples and illustrations of diverse nature have been given, some more convincing and logical than others, and it is shown that the product of the inevitable uncertainties is always of the order given by this principle.

We get from the principle a co-relation between the electron waves and the electron which indicates a mathe-

matical and not a physical meaning to the waves. If a single electron has a given constant velocity, the de Broglie waves have a single definite wave length and velocity, and the group extends to infinity, the "wave intensity" being everywhere the same and all positions equally probable for the electron. If the de Broglie waves form a limited group this must be the resultant of a range of wave velocities, the shorter the group the greater being the range of velocities. But we cannot imagine the electron as having more than one total velocity at an instant; the group corresponds with the range of velocities possible for the electron, that is, with the uncertainty with which theoretically the statement of its velocity must be associated. The greater the uncertainty in the velocity the shorter the group and therefore the smaller the possible range of position.

In applying this to light we have not to deal with electrons, but must postulate entities which we might call photons or quanta, possessing energy and momentum; in vacuo their velocity is the velocity of light, and, corresponding with the de Broglie waves, we have what we call light waves travelling with the same velocity. The momentum of the photon, and the energy, are proportional to the frequency of the wave. In the case of a perfectly monochromatic beam of light the momentum is fixed with certainty, but as we are dealing here with an infinite train of waves, there is complete uncertainty in the position of the photon. If such a beam is limited in length, for example, if a beam of mono-chromatic light is admitted through an aperture opened only for a limited time, classical methods show that the beam is no longer perfectly mono-chromatic but a complexity is introduced, there being

now a range of frequencies and therefore a range of possible values of the momentum of a photon. The shorter the beam the greater this range of frequencies and momenta, but the smaller the range of position. If the photo-electric effect could be observed, with ideal conditions, for such a beam of light the range of velocities of emission of electrons would increase as the length of the beam of light was reduced.

If this principle is correct, that we may not aspire even to an asymptotic approach to complete exactness, it leads to the conclusion that we shall never be able to make a picture of the atom which we can *prove* to be correct. Before its statement we may not have had any great expectation of doing this but we did not think that it was inherently impossible.

Of course, an immediate question arises; if the electron waves are mathematical fictions describing our knowledge or lack of knowledge concerning the electron velocity, how do we account for the diffraction effects which indicate an objective reality? If a beam of electrons falls on to a crystal surface, the widths of the various reflected beams give a measure of the range of velocities of the incident beam. If only one electron is considered, its path, after reflection, lies within a range which depends upon the uncertainty with which its velocity is associated, that is, the more accurately we can measure the velocity, the smaller the possible range of paths. It appears, at first, as though the behaviour of the electron is, to some extent, contingent on our skill in measurement, but, actually, the range of paths depends not on the precision with which we are able to measure the electron velocity, but on that with which we could do so given infinite skill, that is, on conditions of experiment. What we can say is, that certain phenomena



are observed with electrons which are consistent with the idea of electron waves satisfying definite relations between wave length, wave velocity, and electron velocity. We are unable to give any other hypothesis equally consistent with observations, but this is no proof of the reality of the waves. It is always possible that an alternative theory may be advanced, discarding, not only the idea of electron waves, but, also, the earlier concepts of the electron. The picture given on any such theory we must take simply as an expedient assisting us to formulate laws of occurrence of events.

Actually, the electron waves are on all fours with light waves in the question of objective reality. If we take the idea of photons or light quanta as the basis of our picture, light waves can be regarded as the guides or controls of the energy and momentum-carrying photons; we have similar uncertainty considerations. In each case the wave can be regarded as a mathematical device, enabling us to describe the behaviour of the "particle." We have a prejudice in favour of the light wave, because, for nearly one hundred years it was only the wave phenomena which were manifest, the corpuscular aspect of light coming into evidence later. With electrons, we had first the corpuscular aspect and now, here too, we have both.

If we consider the various phenomena of interference and diffraction of light, we find that we have phenomena, which we can reconcile with the idea of a wave motion, with a periodic effect, associated with which are a certain frequency and wave length, but, actually, we deduce these results by analogy with waves of other kinds; we have no actual knowledge that there is a frequency involved, all we can say is, that this is a way of accounting for the observations. It is true that in the case of electric

waves, which we regard as being light waves of great wave length, we have definite evidence of a frequency; we can with our eyes see periodic variations in illumination accompanying the production and reception of these waves, and we might interpret this as showing the objective reality of these long waves, and, therefore, of the shorter light waves. There can be pointed out a possible difference in the nature of the producing and receiving apparatus of the two classes of waves; in the case of light waves these are single atoms or molecules, but with electric waves bodies of relatively large size, composed of enormous numbers of atoms. Further, arise questions of the evidence of our "senses," sight, hearing, touch, etc., as a criterion of objective reality, but this is ground which the physicist has succeeded, generally, in avoiding.

#### CONCLUSION AND SUMMARY

The outstanding points in recent developments are (1) that our physical laws do not enable us to predict precisely what will happen under specified conditions, but only to determine the relative probabilities of a number of possible events, and (2) that there is a limit to the precision with which the state of a particle can be described so that we shall never prove that any picture we make of an atom and its processes is correct.

These limitations need not be discouraging; the first in no way prevents us from making our statistical laws more and more exact, that is, the laws dealing with collections of large numbers of the particles concerning which we have probability laws; on the contrary, the greater our knowledge concerning probabilities the more satisfactory the basis for the laws describing the behaviour of the larger objects, the greater our chance of improving that

working knowledge which is the foundation of all applications of physics.

As regards the second limitation: we cannot prove that a picture is correct, but it does not prevent us from using one to assist us in using and extending our knowledge. We may use a hypothetical aether, or hypothetical waves of one kind or another, and any other devices which will assist us to formulate physical laws to assist in our problems. To be told that the aether is imaginary, that there are no such things as light waves or electron waves is no more serious than to be assured that a collection of mathematical symbols has no objective meaning. The one—like the other—might be quite meaningless and yet might be a real and powerful aid to progress.

A survey of the changes of our generation can, on the one hand, induce in us a proper sense of humility at the realisation of human limitations, but, on the other, the achievements of the great thinkers and experimenters of our age must be a source of admiration and inspiration to all who seek the truth.

# A NEW COLORIMETRIC METHOD FOR MEASURING THE HYDROGEN ION CONCENTRATION OF NATURAL WATERS.

By DAPHNE GOULSTON, B.Sc.

(Communicated by Professor H. G. Chapman.)

*(Read before the Royal Society of New South Wales, June 3, 1931.)*

This method consists of comparing the intensity of colour produced when the indicator is added to the solution of unknown pH, with a standard depth of colour in a Dubosq colorimeter (for description of colorimeter see Hawk's Practical Physiological Chemistry, page 509).

It is evident that the indicator must have only one colour; for instance, it may be yellow in the alkaline form, but colourless in the acid form, or vice versa.

The hydrogen ion concentration of the unknown solution was calculated from the formula:—

$$H = K_{1A} (1 - a/a)$$

or the more convenient form:—

$$pH = \log. 1/K_{1A} - \log. 4a/1-a$$

(see Clark's Determination of Hydrogen Ions, Chap. 8), where  $K_{1A}$ , the so-called apparent dissociation constant, is a function of  $K$ , the true dissociation constant, and the constants of tautomeric equilibria; and  $a$  represents the degree of colour transformation.

## Technique.

0.1 cc. of 0.1% aqueous solution of para nitro phenol was carefully measured into each cup of the colorimeter. To cup (A) was added 20 cc. of N/100 NaOH (any alkali to transfer all the indicator into the alkaline form), producing a fairly deep yellow colour. This formed the standard. 20 cc. of the unknown sample was added to cup (B).

Cup (A) was set at, say, mark 20 on the scale of the colorimeter and the cup (B) was raised or lowered until a good match was obtained in the optical field. If the position of cup (B) on the scale was read at the mark 40, then  $a = 20/40 = 0.5$ , i.e., half the amount of indicator was present in the acid form and half in the alkaline form.

The method was checked by comparing a buffer solution of known pH with the standard. Kolthoff's buffer solution 0.1 M  $\text{KH}_2\text{PO}_4$  and 0.5 M borax was employed. The mean of ten readings on the scale was taken to find  $a$ .  $\text{Log. } 1/K_{1A}$  or p. nitro phenol at  $20^\circ\text{C.} = 7.16$ . The agreement between the buffer pH figures and the standard p. nitro phenol figures is shown below:—

$a$	pH	pH	pH buffer
3.8/40	6.18	6.2	6.2
8.8/40	6.61	6.6	6.6
8.6/40	6.59	6.6	6.6

A 0.3% solution of meta-nitro phenol, which has a  $\text{log. } K_{1A} = 8.32$  at  $20^\circ\text{C.}$  was also used as the indicator.

$a$	pH	pH	pH buffer
8.6/40	7.789	7.8	7.8

All experiments were carried out in a room temperature of about  $20^\circ\text{C.}$

The above method was employed to find the pH of sea water. The following results were obtained:—

	Date	Indicator	pH	pH Gillespie's method
Circular Quay ..	27 Sept.	M.N.P.	7.95	7.95
Circular Quay ..	3 Oct.	M.N.P.	7.93	7.95
Circular Quay ..	4 Oct.	M.N.P.	7.93	7.95
Bottle only half full, analysed 3 weeks later ..		M.N.P.	7.72	7.75
		P.N.P.	7.68	7.70
Farm Cove .. ..	26 Oct.	M.N.P.	8.05	8.05
Farm Cove .. ..		M.N.P.	7.93	7.95
Coogee .. . . .		M.N.P.	7.94	7.95
Bondi .. . . .		M.N.P.	7.93	7.95

When this method is employed to determine the pH of a solution, three errors have to be taken into consideration, namely:—

- (a) The two-acid error
- (b) The salt error
- (c) The temperature error

(See Michaeli Hydrogen Ion Concentration, p. 48.)

(a) In the determination of the pH by indicator methods we add to the given solution some indicator which is an acid. If the solution, e.g., sea water, is poor in buffer value, the addition of acid will alter the pH of our solution, as is illustrated in Michaelis table:—

Concentration Indicator Mols./litre	pH	Error in pH due to Indicator
0.003	7.23	— 0.29
0.0015	7.33	— 0.20
0.00075	7.41	— 0.11
0.00037	7.46	— 0.06
0.00018	7.49	— 0.03
0	7.52	

Therefore, if 1 cc. of indicator is added to 20 cc. of the water, a correction of plus 0.2 must be made in the pH observed.

(b) Kolthoff gave a salt correction, for para nitro phenol, of minus 0.05 pH for an 0.50 N NaCl solution (see Clark, p. 121).

(c) Michaeli (see Clark, p. 131) showed the effect of temperature on the indicator employed in the following table:—

	Log. $1/K_{1A}$ = pH value		
	Temperature		
	10°C.	20°C.	30°C.
p-nitro phenol	7.27	7.16	7.04
m-nitro phenol	8.43	8.32	8.21

## THE SPLENECTOMY OF TADPOLES.

BY DAPHNE GOULSTON, B.Sc.

(Communicated by Professor H. G. Chapman).

*(Read before the Royal Society of New South Wales, June 3, 1931.)*

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It is well-known that the spleen is not essential to the life and good health of adult men and women. The object of the present work was to ascertain whether the absence of the spleen influenced the metamorphosis of the larval frog in any obvious way.

The animals used in the experiment belonged to the genus *Limnodynastes* and were the largest obtainable at that period (from ponds at Marrickville, Sydney), being about 7.5 cm. in length and possessing small hind limbs. Urethane was employed as the anaesthetising agent. The animal was placed in a glass receptacle, containing about a cupful of water and a teaspoonful of urethane, until the animal just ceased to move when disturbed. This solution may be used repeatedly. The larva was immediately transferred to a wide but shallow glass dish containing tap water and some cotton wool to keep the animal in whatever position desired.

The quiescent state of the larva was maintained by the addition of several crystals of urethane whenever the animal showed signs of moving, when the skin was pinched gently with the forceps. If aquatic respiration shows signs of waning the solution must be diluted immediately for the animal is easily killed by an overdose of urethane. The tadpole was laid on the cotton wool with its left side uppermost, and a very small opening, less than 1 cm. in length,

was made through the skin and abdominal wall into the coelome or abdominal cavity. The incision was made just below where the fore limb would later make its appearance through the spiracular opening of the opercular cavity. The viscera was gently explored until the fat body, a yellow body with many finger-like protrusions, and glistening with fat globules, was found. By pulling this fat body gently and carefully, the spleen, a red organ, about the size of a pin's head or less, and rounded or angular in shape, and attached to the folds of the mesentery, was brought into view. Since it was impossible for one person to hold and ligature the spleen, this organ was simply snipped off with a scissors. The fat body broke so easily under the pressure of the forceps when searching for the spleen, that it was thought best to extirpate the entire organ in every case, to make the results comparable. In cases where the spleen could not be found immediately, the laparotomised larvae were used as controls. The wound was closed by sewing the whole integument together, using the finest "eye" catgut. Except that the catgut was stored in alcohol and the needles placed in a dilute solution of lysol, when not in use, no antiseptic precautions were practised. The needle (a straight cutting needle, one inch long) and catgut were washed in clear tap water before using them.

About one dozen of both the splenectomised and control tadpoles died within 1-2 days of the operation. Six splenectomised and ten normal larvae, during 3-4 weeks developed quite normally, as far as the eye could discern. In the case of the splenectomised tadpoles the tail diminished to a mere stump, while both forearms developed and the frog-like appearance was assumed.

The animals died, owing, I assumed, to bad aeration in the hastily improvised aquarium. The control animals,



which had been kept in an old, well-established aquarium, lived for months.

Sections, stained with haematoxylin and eosin, of the organ removed were identified histologically as splenic tissue. That the spleen had been extirpated and that no regeneration had taken place during 3-4 weeks was proved by a post-mortem dissection of the developed animal.

In conclusion, it may be stated that there was no evidence of any deviation from the normal course of metamorphosis of the tadpole following splenectomy.

## VARIATIONS OF THE HYDROGEN ION CONCENTRATION OF SEA WATER.

BY DAPHNE GOULSTON, B.Sc.

(Communicated by Professor H. G. Chapman).

*(Read before the Royal Society of New South Wales, June 3, 1931.)*

Gillespie's simple colorimetric method for obtaining the pII of solutions seemed most suitable for the purpose in hand. To prepare the standard series of colours 1 decigramme (0.1 gm.) of the dry powder of phenol red was placed in a sterile glass bottle and 5.7 cc. of N/20 NaOH were added. When the powder was dissolved the solution so formed was diluted with distilled water to 25cc. This gave a 0.4% solution of the original dye. For use in experimental work, 5 cc. of the stock solution was made up to 100 cc. with distilled water giving a 0.02% solution.

Clean rimless test tubes of uniform bore were carefully selected with the aid of a wooden peg, and also tested by pouring 10 cc. of water into each tube and discarding the unsuitable tubes. The test tubes were then washed with distilled water and steam sterilised for three hours.

The N/100 solutions of sulphuric acid and sodium hydroxide to be used were sterilised by boiling. The corks to fit the test tubes were also boiled and the wax for sealing purposes was filtered to be freed from dust. The test tubes were placed in a paired series and 0.02% phenol red solution added in the drop-ratio of:—

A series: 0.50 cc. 0.55 cc. 0.60 cc. 0.65 cc.

B series: 0.50 cc. 0.45 cc. 0.40 cc. 0.35 cc. etc.

To each test tube of one series were added 10 cc. of N/100 acid and to the other series N/100 base. One drop of pure xylene, from a capillary tube, was added to each tube to prevent growths of moulds or bacteria. The tubes were then sealed with corks that were freshly sterilised and waxed, and labelled.

A trial series of drop-ratio:—

A series: 0.555 cc. 0.550 cc. 0.545 cc.

B series: 0.445 cc. 0.450 cc. 0.455 cc.

of the indicator was made up, but since it was difficult to appreciate the difference in adjacent shades of colour in the centre of the series, the former series was employed. The pH of each pair of tubes was calculated, using Clark's dissociation constant for phenol red (phenol sulphon phthalein).  $K_a = 1.2 \times 10^{-8}$  or  $pK_a = 7.9$ , and employing the formula:—

$$Ch = K_a (\text{undissociated molecule}) / \text{anion}.$$

There was a difference of 0.2 pH between the figures thus obtained and those of Gillespie's drop-ratio figures, so, using I. M. Kolthoff's buffer mixture of borax and acid potassium phosphate a new colour series was obtained as follows:—

Acid phosphate of potassium was recrystallised two or three times, dried to constant weight at 110-105°C. The salt dissolved clear. High grade commercial borax was also recrystallised and constancy of weight established in a desiccator. Stock solution of 0.1 M potassium H phosphate, i.e., 13.61 gm/litre, and 0.05 M borax, i.e., 19.10 gm/litre, were made with distilled water.

The buffer series was prepared from Kolthoff's table.

Potassium H Phosphate	Borax	pH
6.23 cc.	3.77 cc.	7.0
5.81 "	4.19 "	7.2
5.50 "	4.50 "	7.4
5.17 "	4.83 "	7.6
4.92 "	5.08 "	7.8
4.65 "	5.35 "	8.0
4.30 "	5.70 "	8.2
3.87 "	6.13 "	8.4
3.40 "	6.60 "	8.6

When the drop-ratio series was compared in a comparator with the series of buffer mixtures, Clark's and Kolthoff's, were found to coincide approximately.

For collection of a sample of water, a light blue coloured bottle of common glass was cleaned and rinsed with the sea water to be tested, and a sample taken. The pH of the water was obtained by pipetting 10 cc. of the sample into a tube of the same bore as the standard pH series, and adding to this 1 cc. of 0.02% phenol red solution. The tube was then placed in the centre compartment of a comparator with a test tube of distilled water immediately behind it, and the colour compared with the shades in the prepared standard series. Two trial samples were taken from Coogee beach, and the Spit. The pH of both was 8.5 and six days later this pH was unaltered, so it was concluded that no alkali had been absorbed from the glass of the collecting bottle in any appreciable quantity. This particular kind of bottle was, therefore, considered suitable for the collection of samples of sea water. The room temperature in which the pH experiments were carried out varied from about 20° to 22°C., and the pH figures obtained were not corrected for temperature or salinity. McClendon found that under normal conditions the pH of the sea water falls 0.01 for 1°C. decline in temperature, and a correction of -0.01 should be applied to the pH for every unit rise in the salinity above 0.33%.

Of the samples taken from the coast near Sydney, Cronulla, La Perouse, Bondi, Manly, Collaroy, etc., 60% showed a pII of 8.5, and 40% gave a pH of 8.4. Since this figure is so near the end of the phenol red curve, it was thought advisable to check the figure by employing another indicator.

A stock solution of cresol red, ortho-cresol sulphon phthalein was prepared by dissolving 0.1 gm. of the dry powder in 5.3 cc. of N/20 sodium hydroxide and diluting to 25 cc. with distilled water. This 0.4% solution was 0.02% for experimental purposes. Clark's dissociation constant for cresol red is 8.3 pKa. A standard drop-ratio series with cresol red as the indicator was prepared as before. Two samples of sea water from Cremorne and Circular Quay gave a pII of 8.4 with both the phenol red and the cresol red series. The alkalinity of the sea water in contrast to the neutrality or acidie character of tap and distilled waters was also shown by means of phenolphthalein and litmus paper; sea water changing sensitive litmus paper first mauve, then blue, within five minutes; both tap and distilled waters, on the other hand, turned blue litmus paper pink, the intensity of pinkness being greater in the case of distilled water than the tap. When a drop of phenolphthalein was added to sea water a very distinct pink colour resulted, while tap and distilled waters, when similarly treated, remained colourless.

The hydrogen ion concentration of the sea water on the open sea shore seems to change slightly, since of the samples taken from Coogee beach, most were of a pII of 8.5, while some showed a pII of 8.4, and the pH of one sample was 8.6. As one travelled from the ocean, through the harbour and up the rivers, the alkalinity of the water decreased perceptibly within a mile or so, as is demonstrated from the following figures:—

Lane Cove River . . . .	Valentine . . . .	pH 8.4
	Tambourine . . . .	8.3
	Figtree . . . .	7.8
	Fairy Bower . . . .	7.4
Parramatta River . . . .	Harbour . . . .	8.4
	Long Nose Pt. . . .	8.3
	Drummoyne . . . .	8.2
	Gladesville . . . .	8.1

This reduction of the alkalinity of the water is probably due to several factors, such as a lessening in the amount of Ca and Mg hydroxides, which cause the general alkalinity of sea water; a pouring out of fresh and brackish water from the rivers; and a proportional increase in organic life.

A modification of a Van Slyke apparatus was employed in an attempt to find the carbon dioxide content of sea water, but without success. For a pH 8.5 and 7.0 the  $\text{CO}_2$  content was approximately 14%-15%, i.e., 14-15 cc. of  $\text{CO}_2$  was contained in 100 cc. of sea water. The difference in the  $\text{CO}_2$  content of water of a pH of 8.5 and 7.0 could not be measured by this method. The relation of the hydrogen ion concentration of sea water to its  $\text{CO}_2$  tension was found in the following manner. A glass bottle of a capacity of about 560 cc. volume was cleaned, and rinsed with the sea water to be examined. About 15 cc. of sea water sample were then run into the bottle, and a minute quantity of  $\text{CO}_2$ , from a Kipp's apparatus, was run into the bottle (the  $\text{CO}_2$  being first passed through distilled water to remove any trace of HCl vapour). The bottle was then made air tight with a vaselined glass stopper, and shaken vigorously for a few minutes. About half an hour was allowed for equilibrium to become established between the air and water. The bottle was again shaken, and a sample of the air was taken into a glass syringe, and the pH of the water was obtained immediately in the usual way. The sample of air was analysed for  $\text{CO}_2$  in a Haldane's gas analysis apparatus. The barometric pressure, and the temperature

of the gas analysed, were also noted. A graph was obtained from separate samples of water of the same natural pH of 8.4.

This graph shows that sea water is slightly buffered, although as small an increase as 8 mm. in the  $\text{CO}_2$  tension sufficed to alter the pH from 8.5 to 7.0. The buffer action was also shown by titration. One cc. of phenol red was pipetted into a clean test tube of the specific diameter for the phenol red series, and 10 cc. of the sample of sea water added. This was titrated with N/200 sulphuric acid until the colour was of the same tint as the pair of tubes of pH of 7.0. The colours were compared in a colorimeter. Ten cc. of the sample of sea water required 1.3 cc. of N/200 acid to increase the acidity from pH 8.5 to pH 7.0.

i.e.:  $6.5 \times 10^{-4}$  g.m. H ions were added to bring the pH of 1,000 cc. of sea water from 8.5 to neutrality.

$9.7 \times 10^{-8}$  g.m. H ions would suffice to do this in the case of distilled water.

The fact that the pH of the ocean water does not remain constant is shown in the following figures:—

Palitzsch	Black Sea	pH 8.34 (surface) 7.45 (deep)
Mayor	Yarmouth Sargasso Sea Florida	7.95 (cold) 8.25 (tropical) 8.60 (at reef flat) 8.25 (away from reef flat)
Mayor	Gulf of St. Laurence Gulf Stream	pH 8.0-8.1 8.2-8.4
Goulston	Sydney	ph 8.4-8.5 (sea shore) 8.1-8.4 (river to harbour)
Henderson and Cohn	Salinity: 30.73 34.60 0°C. 40°C.	8.03 ( $\text{CO}_2$ tension constant) 7.87 (salinity constant) 8.35 8.32 7.95

McClendon states that it is almost certain that the  $\text{CO}_2$  tension is the chief factor in determining the pH of oceans. When McClendon diluted sea water of pH 8.1 with an equal volume of conductivity water of pH 6, the resulting pH (using H electrode) was 8.09; while a jelly fish, pulsating in a closed vessel, changed the pH from 8.2 to 8.0 in a short time, indicating an increase of about 6.5 cc. of  $\text{CO}_2$  per litre. He also maintains that temperature is the most important factor determining the pH of the surface water of the sea; for as the temperature rises carbon dioxide is driven out of the water and alkalinity increases; whereas if the temperature falls, the water attains an increased capacity for absorbing  $\text{CO}_2$ , derived from the animals and plants, and the pH increases.

Sir William Herdman found that a periodic seasonal change in the alkalinity of sea water corresponded roughly with the phytoplankton annual curve.

"In early spring the rapidly developing myriads of diatoms in their metabolic processes use up the store of CO accumulated during the winter, or derived from the bicarbonates of Ca and Mg, and so increase the alkalinity of the water, until the maximum of alkalinity, due to the fixation of the carbon, and the reduction in the amount of  $\text{CO}_2$  present, corresponds with the crest of the phytoplankton curve in April or May.

The ability of different species of marine fishes to extract oxygen from sea water at different pH's varied. For example, Powers found that the Cunner was able to extract  $\text{O}_2$  from the water when the pH was 8.4 or 6.6; whereas the optimum  $\text{O}_2$  intake of the Mackerel was limited between pH 7.7 and 8.2. This fact may be correlated with the range of habitat of the species.

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## ON THE METABOLISM OF COLD-BLOODED ANIMALS.

BY DAPHNE GOULSTON, B.Sc.

(Communicated by Professor H. G. Chapman.)

*(Read before the Royal Society of New South Wales, June 3, 1931.)*

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### Introduction.

Few determinations are available concerning the consumption of oxygen and elimination of carbon dioxide by cold-blooded animals. Such determinations as have been made have not been correlated with the surface area of the animals. I have, therefore, made some determinations of the metabolism of frogs and have related the metabolism to the results of these determinations.

### Method of Determining Surface Area of Frogs.

The frogs were killed by pithing the brain and spinal cord. Since the weight of a frog varies appreciably according to whether it occupies a moist or dry habitat, all the frogs were rinsed in tap water and the superfluous water absorbed by slightly damp filter paper previous to weighing. Six frogs were chosen varying in weights from 6.8 to 31.1 gm. and plaster of paris casts were made as follows:—

The frog was laid on its dorsal surface on a plate of glass with its fore and hind limbs placed so as to be freed from touching the trunk of the animal. No attempt was made to separate the digits of the manus and pes.

The animal was effectively halved by outlining the body, fairly thickly, with plasticene, so that the plasticene made contact with the skin of the animal at approximately

half the thickness from the dorsal to ventral surface. A plasticene wall about  $1\frac{1}{2}$  ins. high was then built around this structure, and a thin layer of oil was painted over the plasticene. Fresh plaster of paris was added to water and a fairly heavy creamy consistency was obtained, and the mixture immediately poured into the frog-plasticene structure.

When the plaster had hardened (about 20 minutes later), all the plasticene was removed, and the plaster surrounding the frog was painted with shellac, which dried almost immediately, and then with oil. A fresh plasticene wall was now built round the half plaster cast and plaster of paris was poured into the plasticene cast structure and again left to harden.

The two halves were gently pulled apart and the dead frog carefully removed. The casts were shellaced and left to dry.

The casts were next lined, as thoroughly as possible, with wet japanese silk by means of a hard brush and commercial adhesive paste. When dry the lining was gently pulled free from the cast and the "frog shape" cut into fragments small enough to lie flat.

A sunlight print was obtained of all the fragments, and the weight and area of the sensitised paper obtained. Each small piece representing a portion of the surface area of the frog was next carefully cut out, and the weight of the sum of these pieces obtained.

If Y sq. cm. equal the total area of the sensitised paper  
 Z gm. equal the weight of the sensitised paper  
 X gm. — weight of fragments

$$\text{Surface area} = \frac{Y \cdot X}{Z}$$

The accuracy of the method was tested by pasting japanese silk around a billiard ball, and treating this surface covering in the same way as above.

Calculated	Experimental
Surface Area.	Surface Area.
80.20 sq. cm.	80.65 sq. cm.
	80.00
	81.50
	80.30 sq. cm.

The surface area figures for the frogs were less accurate, due to the difficulty of lining the cast. For example:—

Weight—frog	31.1 gm.	Surface Area.
		100 sq. cm.
		102
		105
		101
Mean		102 sq. cm.

Using Meeh's formula relating the surface to the volume:

$$\text{Surface} = K \text{ Volume}^{2/3}$$

The specific gravity is practically constant, so that weight may be substituted for volume in this expression:—

$$\text{S.A.} = K^3 W^2$$

Figures obtained for K constant as follows:—

K	10.26
	11.63
	12.06
	11.58
	11.79
	12.30
	<hr/>
	11.60
	Mean.

Inabas (Archiv. Anat. Physiol. 1911) found:—

K for lizards = 12.4 (wt. 4 to 8 gm.)

12.79 (wt. 20 to 26 gm.)

K for frogs = 4.6

To obtain this constant K, Inabas measured the skin after its removal from the animal.

This method would only give a true figure when the skin neither stretches nor shrinks on its removal from the body. Inabas' constant for lizards is of the right order of magnitude, but his frog constant is a long way out, due to the shrinkage of the frog's skin.

The following figures for K have been found for various animals:—

K Dog = 10.10 (Wt. 1 kg. approx.)

Cat = 10.27 (Wt. 1 kg. approx.)

(Karl Thomas, Archiv. Anat. Physiol. 1911)

K Man = 12.5

Dog = 11.2—10.3

Cat = 9.9

Mouse = 11.4

(Rogers—Comparative Physiology, 1927.)

My surface area figures were obtained from experiments with winter frogs, so that probably a different value for constant K would be found for female frogs, during the breeding season, due to their increase in girth.

Cowgill and Drabkin (Amer. Journ. Physiol. 1927, No. 1) experimented with dogs and have added to the Meeh Rubner surface area formula to allow for the nutritive state of the animal, producing the following expression:—

$$S \text{ sq. cm.} = KW^{0.7} \text{ gm.} \times N_m / N_{\text{obs}}$$

where  $N_m / N_{\text{obs}}$  = nutritive state correction

$N_{\text{obs}} = W^{1/3}/\text{length of individual in question}$

$N_m = \text{Maximum possible } W^{1/3}/L \text{ for the species.}$

Dreyer found, and Cowgill and Drabkin confirmed, with the data from Stewart and Thomas, the fact that the exponent of the weight should be 0.71 instead of 0.667 ( $2/3$  power).

With exponent 0.667	K mean is	$\pm 5.4\%$
„ „ 0.71	„	$\pm 2.9\%$

Frog	Weight	Length	$N_{\text{obs}}$
A	31	6.8	0.462
B	13	5.1	0.461
C	7	4.5	0.425
D	9	5.1	0.407
	10	5.1	0.423
E	16	5.9	0.427
F	19	6.1	0.437
F <sub>1</sub>	23	6.1	0.466

F<sub>1</sub> is frog F allowed to remain between wet filter paper overnight.

### The Metabolism of Frogs.

The only data concerning the direct calorimetry of frogs was obtained by A. V. Hill (Journ. of Physiol. Vol. 13, 1911). Hill designed a micro-calorimeter. Two thermos flasks were arranged each in contact with one junction of a sensitive galvanometer, which was connected to a copper constant thermocouple: so that when the animals plus some water were placed in one flask, and some water in the other flask, the deflection of the galvanometer mirror gave the difference of temperature between the two flasks. The difference was increased by the heat-producing activity of the living animals.

100 cc. frogs (8 frogs)  
150 cc. water  
in A flask.  
285 cc. water  
in B flask.

Hill found that the living resting frog produced about 0.45 calories/cc. frog at a temperature of 19° C.

The average volume of a frog was 12.5 cc. and the surface area was 62 sq. cm. (using D. Goulston's constant  $K = 11.6$ ).

A resting frog, therefore, produced 20.77 cal./sq. metre /day.

### *Hyla Aurea.*

The following experiment was an attempt to ascertain directly the resting metabolism of an individual frog. The same frog was used throughout all experiments.

Only water had been supplied to the animal one week (at least) previous to, and during, the experiments.

The frog was placed in a wide-mouthed jar of capacity of 1150 cc. The jar was closed with a stout rubber stopper through which passed an "inlet" and "outlet" glass tubing. The inlet tube was connected by rubber tubing to a series of five absorption tubes containing 40% KOH; while the outlet tube was connected to an aspirator. A cloth was draped round the jar to prevent the animal from being disturbed.

Air freed from CO<sub>2</sub> was drawn through the experimental jar for one hour. The outlet tube was then disconnected from the aspirator and some air drawn through into a sampling tube. The inlet and outlet tubes were immediately closed with pinch-cock stoppers. (Later glass taps were substituted.)

The animal was allowed to remain thus for a period of three hours. The tap water, which operated the aspirator, was allowed to continue to run so that the animal would not be disturbed by an unnecessary change in its vicinity.

After the experimental period had elapsed, another sample of air was taken from the jar, care being taken to obtain a well-mixed sample by raising and lowering the plunger of the sampling tube several times.

The "before" and "after" samples of air were analysed in a Haldane gas analysis apparatus. The following figures were obtained:—

PRELIMINARY METABOLISM FIGURES FOR RESTING FROGS.

Date	CO <sub>2</sub> % expired	O <sub>2</sub> % absorbed	Time hours	Weight gm.	Calories/sq. metre/day		Temp- erature 0° C.
						R.Q.	
4	0.46	0.51	3	16.1	27.88	0.90	23
8	0.34	0.38	3	14.6	22.46	0.97	24
9	0.29	0.35	3	14.0	20.24	0.83	24
10	0.22	0.30	3	14.6	17.45	0.73	21
11	0.22	0.30	3	14.2	17.03	0.73	19.8
12	0.19	0.27	3	14.4	15.78	0.72	20.3
17	0.17	0.23	3	14.1	13.48	0.74	19
19	1.39	1.65	22	13.4	14.11	0.84	20-22

Weight	Surface Area
13 gm.	64.2 sq. cm.
14 gm.	67.4 sq. cm.
15 gm.	70.5 sq. cm.
16 gm.	73.7 sq. cm.

The above figures show that the metabolic rate of a resting frog falls during starvation.

Hill found, as shown in his graph, that the heat production of frogs, kept without food, fell from an initial high value of 0.5 calories per cc. frog to 0.3 calories at



20° C. This fall took place gradually, and was not complete until about 15 days.

This corresponds to a fall of metabolism from 24 calories/sq.m./day to 14 calories/sq.m./day.

The rate of heat production of a frog is increased 2-3 times by a rise of 10° C. as demonstrated below:—

27° C.	..	0.7	calories/cc./frog/hour
20° C.	..	0.5	„ „ „ „
0.3° C.	..	0.2	„ „ „ „

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THE MINERALOGY AND ORIGIN OF THE  
NATURAL BEACH SAND CONCENTRATES OF  
NEW SOUTH WALES.\*

By H. F. WHITWORTH, B.Sc.

(With twenty Text Figures.)

(Communicated by C. A. Sussmilch.)

*(Read before the Royal Society of New South Wales, June 3, 1931.)*

**Occurrence.**

At many places along the coast of New South Wales, between the mouth of the Shoalhaven River on the south, and the Queensland Border on the north, deposits of naturally concentrated heavy minerals occur on the beaches. The minerals have been concentrated by wave action during heavy south-east gales, and the deposits are usually best developed from the centres to the northern ends of the beaches. The most extensive deposits occur on the beaches to the north of Port Macquarie, those on the Southern beaches being much smaller. Raised beaches, only a few feet above sea-level, occur on the North Coast, and many of these contain layers of heavy mineral concentrates. In localities such as these, in which the waves are eroding the raised beaches, the deposits of concentrates on the present day beaches are particularly heavy, sometimes reaching a thickness of three feet, a width of twenty yards, and a length of over a mile after a heavy storm.

During periods of fine weather, the concentrates dry and become remixed with the beach sand, largely by the action of the wind, but at each high tide, a line of black sand is usually left at high water mark, thus indicating the presence of heavy minerals in the sand.

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### **Economic Importance.**

The beaches and raised beaches of the North Coast have been worked intermittently during the past thirty-five years or so, for their gold, platinum, tin and monazite contents, but have failed to yield a satisfactory return. A large part of the work has been done by fossickers, who confined their attention to the heavy concentrates or "sniggers" formed during storms. More recently some attention has been paid to some of the South Coast beaches, and in 1925 a little cassiterite and gold were obtained from the beach at Thirroul. As the amount of concentrate on this beach is small, operations were conducted on a small scale, and have since been abandoned. Although both gold and cassiterite are known to occur on other beaches on the South Coast, little or no work has been done on them.

Attention is now being paid to some of the North Coast beaches as a possible source of zircon and rutile, the former for use in the manufacture of zirconia, which is now used as an opacifier in the enamelling of iron and steel, and the latter for the manufacture of titanium white, a pigment of great covering power, now finding an extensive use in the paint industry.

### **Composition.**

The colour of the natural concentrates varies from a pale grey to a very dark grey, according to the amount of ilmenite present, and in some localities, it is so dark in colour that it is commonly known as "black sand." Owing to the fineness of the mineral grains, and their high degree of rounding, the concentrate is extremely mobile when dry.

A microscopic examination reveals the fact that the grading is very even and that the main constituents are zircon, ilmenite and rutile. As these three minerals have similar specific gravities, and as the grains are of approxi-

mately the same size, the percentage weight of each in a given sample may be determined with a fair degree of accuracy by a simple count of the number of grains of each mineral present in a small sample. This count is conveniently made with the aid of a microscope with a magnification of about 200 diameters, immersing the sample in a highly refracting liquid. Nitro-benzene was found to be suitable for this purpose, for, its refractive index being about 1.55, any quartz grains present are rendered almost invisible in ordinary light, whilst zircon and rutile grains stand out in high relief owing to their much higher refractive power. Providing that more than 1000 grains are counted in at least ten different fields of the microscope, the error in estimating the percentage weights of the minerals present does not appear to be high.

The approximate mineralogical composition of a number of samples of natural concentrates from different localities is given below.

Locality.	Zncon.	Ilmenite.	Rutile.	Other Minerals.
Corrumbin ..	53%	27%	13%	7%
Byron Bay ..	43%	36%	13%	8%
Ballina . . . . .	62%	26%	7%	5%
Berrie Point ..	75%	14%	9%	2%
Fingal Beach..	54%	30%	11%	5%
Iluka .. . . .	52%	28%	18%	2%
Collaroy .. .	40%	43%	15%	2%
Thirroul .. .	60%	25%	13%	2%
Terrigal .. .	45%	39%	13%	3%

The term "Other Minerals" in the above table does not include quartz, the presence of which implies imperfect concentration. Some of the samples examined contained about 25% of quartz whilst others were practically free from this mineral. Quartz is easily removed from the heavy minerals by panning or by shaking and dry blowing. Either of these methods will yield a concentrate practically

free from quartz, with the loss of very little of the heavy minerals present.

The following analyses, published in "The Mineral Industry of New South Wales" (N.S.W. Geological Survey 1928) serve to illustrate the chemical composition of the sands:

	No. 1	No. 2
SiO <sub>2</sub>	27.46	20.36
ZrO <sub>2</sub>	50.78	43.77
TiO <sub>2</sub>	14.00	23.50
AlO <sub>3</sub>	1.72	0.34
Cr <sub>2</sub> O <sub>3</sub>	0.42	0.34
FeO	4.83	4.48
MnO	0.25	trace
CaO	trace	absent
MgO	0.42	0.44
P <sub>2</sub> O <sub>5</sub>	0.24	1.25
Rare Earths	trace	1.61
Organic Matter	trace	0.32
SnO <sub>2</sub>	trace	3.81
Gold	1 dwt. 7 gr. per ton	1 dwt. 10 gr. per ton
Platinoid Metals	less than 10 gr. „	less than 10 gr. „

No. 1.—Natural beach sand concentrate from between the Richmond River and Evans Heads. Analyst, J. C. H. Mingaye.

No. 2.—Natural beach sand concentrate from two miles south of Evans Heads. Analyst, H. P. White.

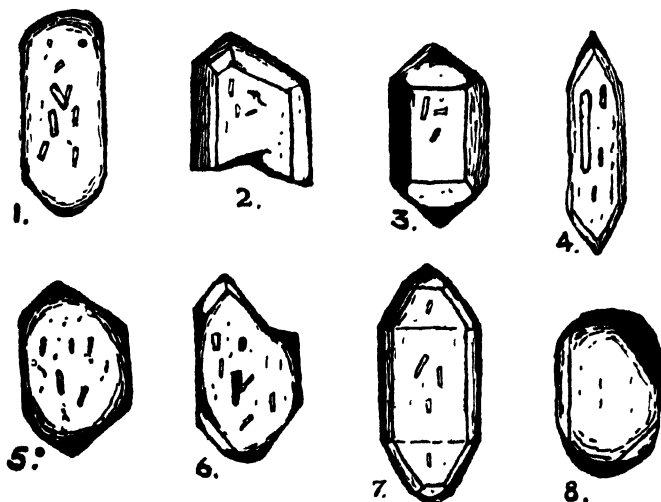
The writer has examined many samples of these naturally concentrated sands under the microscope, and in addition to zircon, ilmenite and rutile, the following minerals have been recognised:—

Leucoxene	Green spinel
Epidote	Brown spinel
Chromite	Cassiterite
Magnetite	Chalcedony
Limonite	Sapphire
Tourmaline	Pyroxenes
Monazite	Hornblende
Xenotime	Andalusite
Garnet	Staurolite
Pleonaste	

Raggatt (Bulletin No. 13 Geological Survey of New South Wales) states that Columbite is present in some cases. Owing to the opaque nature of this mineral, and the presence of a large amount of ilmenite, which is also opaque, it is impossible without the aid of magnetic separation and chemical tests on the separated fractions, to verify the presence of Columbite.

#### Description of the Minerals Present.

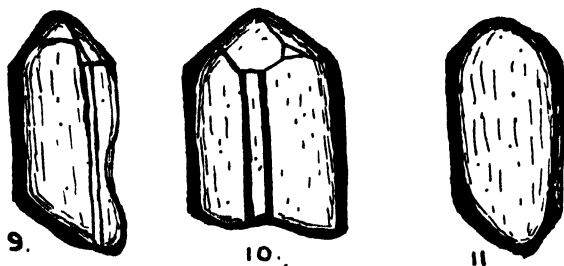
The *zircon* is nearly all of the colourless variety, although a few pale pink and pale blue grains are present. It occurs both as well rounded grains and as perfect doubly-



Figs. 1-8. Zircon crystals separated from beach sand concentrates. Approximate length 0.2mm.

terminated, pyramid capped tetragonal prisms. The crystals average about .2 mm. in length and about .1 mm. in breadth, whilst the rounded grains average about .15 mm. in diameter. The occurrence together of well rounded grains and perfectly preserved crystals, seems to imply that the

crystals have been transported from their original source as inclusions in some other mineral which has protected them from erosion, and which has liberated them comparatively recently. The zircon is easily recognisable from its high refractive index, brilliant lustre on crystal faces, and its high double refraction. The double refraction is so high that most grains show only a high order white interference colour, though some show pale pinks and greens on the edges. Inclusions are common, some are definite crystals of rutile, whilst others appear to be hollow cavities, irregular in some cases, and elongated parallel to the "C" axis of the zircon, in others. Tiny dust-like inclusions, probably of oxide of iron, occur along definite zones in many crystals.



Figs. 9-11. Rutile crystals separated from beach sand concentrates. Approximate length 0.2mm.

*Rutile* occurs as broken or imperfect crystals, or as rounded grains. The colour varies from a deep reddish brown through various shades of brown to a deep yellow. Many of the deeper coloured grains are almost opaque, and unless examined carefully in a very strong light, may be mistaken for ilmenite. The lustre on crystal faces and on freshly broken surfaces is very high, and the refractive index is so high that the lustre is quite noticeable even when

immersed in nitro-benzene, the refractive index of which is about 1.55. The double refraction of rutile is high, and interference colours are masked by the strong natural colour. Pleochroism is weak, and is only noticeable in the lighter coloured varieties. In size, the rutile grains are approximately equal to the zircons, the crystals averaging about .2 mm. in length, and the rounded grains about .15 mm. in diameter.

*Ilmenite* occurs both as imperfect crystals and as rounded grains. It is quite opaque, and of a bluish black colour by reflected light, whilst the lustre is somewhat metallic. Many of the rounded grains of ilmenite show curiously shaped cavities in their surfaces. These grains are probably the eroded remains of the skeletal crystals which are so characteristic of ilmenite. Whilst the average grain size of the zircon and ilmenite is approximately the same, many of the ilmenite grains are very small, some being less than 0.05 mm. in diameter.

*Leucoxene* occurs as a brown, yellow or white coating on the ilmenite grains. Some of the grains of ilmenite are only partially covered with leucoxene, whilst others appear to have been entirely replaced by that mineral.

*Epidote* occurs rather sparingly as rounded yellowish green grains, generally slightly clouded through alteration. It is recognisable by its high refractive index, weak though distinct pleochroism, bright interference colours, and the clouding previously mentioned. The amount of epidote varies greatly in different samples of sands. As the specific gravity of epidote (3.4) is considerably below that of zircon, ilmenite and rutile (4.53, 4.65, and 4.25 respectively) its presence is an indication of imperfect concentration.



*Chromite.* The presence of small amounts of chromic oxide is shown by the analyses previously quoted, and a careful search reveals the presence of chromite in dark brown flakes which are almost opaque, being translucent on the thin edges only. The flakes are isotropic, and possess a very high refractive index. A few brown opaque octohedral crystals of chromite have been noted in some cases.

*Magnetite* occurs rather sparingly and is most easily detected by means of a magnet. The grains separated in this manner are jet black to brownish black in colour, and are often partially altered to limonite. Some perfectly formed octohedral crystals are present.

*Limonite* is present as small reddish brown earthy opaque grains, some of which appear to have a concentric structure. Much of the limonite present appears to be an alteration product of magnetite.

*Tourmaline* is very variable in amount, being very rare in some sands and forming up to 2% of the volume of others. As in the case of the epidote, this variation may be accounted for by the comparatively low specific gravity of the tourmaline (about 3.1). The tourmaline occurs both in the form of rounded grains and as short prismatic crystals with rounded ends. The colours are very varied, blue, pink, brown, black, and yellow grains being present. The pleochroism is very strong, changes being from colourless, yellow or brown to black, blue to pink, blue to colourless, blue to brown, pink to colourless and pink to brown. The characteristic absorption, which is greatest when the prism edge of the crystal is parallel to the vertical cross hair of the microscope, serves to identify any crystals of tourmaline present. The rounded grains are quite easily recognisable by their comparatively low refractive index and low double refraction, and their strong pleochroism.

*Monazite*, owing to its softness, occurs mainly as rounded grains which are slightly below the average grain size of the sands. Many of the grains have a peculiar bean-like or pear-like shape which seems to be characteristic (see figs. 12-14). The colour is pale yellow or yellowish green and pleochroism is absent. The refractive index is high and the grains show a characteristically pitted surface.



**Figs. 12-14.** Monazite grains separated from beach sand concentrates. Approximate length 0.15mm.

The double refraction is about the same as that of zircon, and the grains show a high order white interference colour sometimes showing pale pinks or greens on the thin edges. The amount of monazite varies in different sands, in some cases being present to the extent of over 1%. The specific gravity of the monazite is sufficiently above that of the zircon, ilmenite and rutile to allow it to be concentrated by panning.

*Xenotime*. In the absence of micro-chemical tests, the determination of this mineral is in doubt, but in certain analyses both the phosphorous pentoxide and rare earths are shown in excess of that required for the monazite present. This implies the presence of another phosphate mineral of the rare earth group. Many of the sands examined contain a yellow mineral, often opaque through alteration, crystallising in a manner to the zircon, and

having a very high refractive index and double refraction. This mineral has been provisionally classed as xenotime.

*Garnet* is present in practically all the sands examined, and occurs as irregularly shaped fragments which are not well rounded. Perfectly formed crystals are not present, although occasionally a crystal face may be seen. Both pink and colourless varieties are present. The combination of high refractive index and isotropic character serve for its identification.

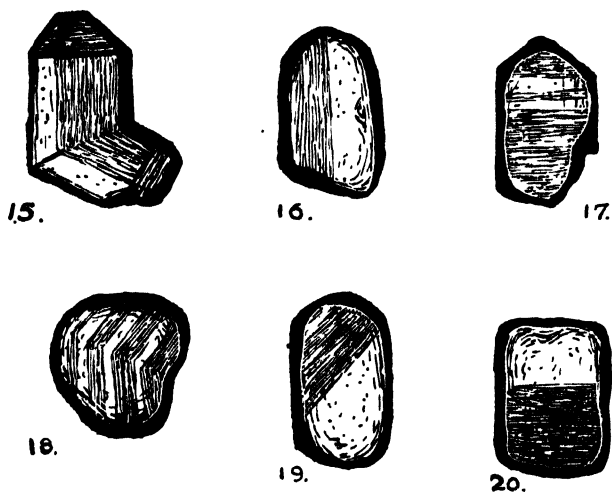
*Pleonaste* is a very rare constituent, and has been definitely recognised in only a few of the many samples of sand examined. It occurs as irregularly shaped grains, which are black in colour by reflected light, and either a dark green or grey on the thinnest edges by transmitted light, the colouring being so strong that the centres of the grains are opaque.

*Green Spinel* is slightly more abundant than the pleonaste, and occurs as bright green grains which may be recognised by their high refractive index and isotropic character.

*Brown Spinel* occurs rather sparingly as dark brown translucent, isotropic flakes, having a high refractive index.

*Cassiterite* usually is a rare constituent, but in some cases owing to its relatively high specific gravity (6.65), it has been concentrated locally and samples containing as much as 25% of this mineral have occasionally been obtained. Most samples of the sands will yield a concentrate rich in cassiterite and monazite by panning. The identification of cassiterite is somewhat difficult owing to its variable colour. The colours are grey, yellowish brown, dark brown, brownish red and colourless. Pleochroism is very faint, and is best seen in the grey coloured grains. Well preserved crystals are rare, but a few prismatic

crystals and geniculate twins have been seen. Many grains are either parti-coloured or zoned, which is a very useful character in the determination of cassiterite. The colour banding in some grains shows sharp changes of direction, as in Fig. 18. Such grains are evidently all that remains of an originally twinned crystal. The refractive index is high and the double refraction is so high that interference colours can seldom be seen even on thin edges.



Figs. 15-20. Cassiterite crystals separated from beach sand concentrates. Approximate length 0.15mm.-0.2mm.

*Chalcedony* is present both as angular fragments and as rounded grains which are either colourless or pale green. It is most easily recognisable by the fact that it fails to extinguish when rotated between crossed nicols, owing to its cryptocrystalline character. Its presence, like that of quartz, implies imperfect concentration.

*Sapphire* is a rare constituent, and occurs as flat basal cleavage plates. It is recognisable by its high refractive

index, weak double refraction, pale blue colour and faint pleochroism.

*Pyroxenes.* Two varieties of pyroxene are present, one being colourless, and the other being pale green and pleochroic, changing to a pale pink when rotated between crossed nicols. The colourless variety is often much clouded by alteration, and is possibly diopside. The coloured pleochroic variety is apparently hypersthene.

*Hornblende* is very rare and occurs as cleavage fragments. It is green in colour, strongly pleochroic, and can be identified by its oblique extinction, comparatively low refractive index and double refraction, and by its well developed cleavage.

*Andalusite* occurs very sparingly as rounded grains, slightly above the average grainsize of the sand. It is recognisable by its comparatively low double refraction and its pleochroism, the colours observed being pale pink or pale bluish green, changing to colourless when rotated between crossed nicols.

*Staurolite* is somewhat irregular in its distribution, and apparently is more abundant in the concentrated sands from the South Coast than in those from the North Coast. It occurs as rounded grains of a brownish red colour, and is identifiable by its strong pleochroism and bright interference colours. Many of the grains of staurolite contain small inclusions which all elongated parallel to the long axis of the staurolite. Some of these inclusions are surrounded by dark haloes in the staurolite.

In addition to the above minerals, there are at least three others which have not yet been definitely identified. One of these is dark brown in colour and has a very high refractive index and double refraction, and is generally

clouded through decomposition. This mineral is possibly sphene. Another mineral is brownish yellow in colour, quite opaque, and occurs as rounded grains with a brilliant lustre. The other unidentified mineral occurs as small prismatic crystals which are dark brown in colour, have straight extinction, and are almost opaque.

#### ORIGIN.

The late J. E. Carne, in discussing the auriferous beach sand concentrates of the North Coast, suggested the following possible sources:—

- (a) The Siluro-Devonian rocks.
- (b) The Clarence River Coal Measure sedimentary rocks.
- (c) The early river channels, i.e., drifts under the Tertiary basalts.
- (d) Auriferous basalt at the Richmond River Heads.
- (e) The present drainage channels from the Eastern margin of the stanniferous rocks of New England.

In the Annual Report of the Department of Mines for the year 1895, Carne discusses all of the above possibilities, and finally favours the theory that the early drainage channels are the source of the concentrates. In view of the fact that concentrates, similar to those of the North Coast, occur on the beaches between the mouths of the Hunter and Shoalhaven Rivers, in districts in which no Tertiary drifts are known, the writer began a series of experiments to determine whether the Triassic sedimentary rocks might not be their source.

Samples of Triassic sandstone from around Sydney were crushed and concentrated by panning, and some interesting results thus obtained. Six samples, each of 1000 grams, were treated by this method and yielded the following amounts of heavy mineral concentrates:—

Yellow sandstone	Dawes Point	.74 gms.
Yellow sandstone	Mosman	.86 gms.
Ferruginous sandstone	Willoughby	.45 gms.
White sandstone	Sailor's Bay	.22 gms.
White sandstone	Wynyard Square	.65 gms.
Yellow sandstone	Miller's Point	.35 gms.

A sample of Triassic sandstone from Broke, near Singleton, yielded only .11 gms. of heavy minerals per 1000 gms.

Several samples were treated in duplicate in order to determine whether the variations in the amounts of concentrate obtained were due to experimental error or not.

In each case the experimental error was found to be small, and it thus appears that there is a considerable variation in the amounts of heavy minerals present in different horizons of the Triassic Series.

A sample of Upper Coal Measure sandstone from near Muswellbrook yielded 0.5. gms. of heavy minerals per 1000 gms.

After warming the concentrates obtained from the sandstone with dilute hydrochloric acid, to remove iron stainings and to dissolve any particles of metallic iron introduced during crushing operations, it is seen that they bear a strong resemblance to the natural beach concentrates. In all cases they consist mainly of zircon, ilmenite and rutile, together with most of the other minerals found on the beaches. In addition to zircon, ilmenite and rutile, the following minerals have been observed:—

Haematite	Monazite	Cassiterite
Limonite	Staurolite	Tourmaline
Garnet	Epidote	Pyroxenes
Magnetite	Hornblende	

The relative proportions of zircon, ilmenite and rutile in the concentrate obtained from the yellow sandstone from Dawes Point are as follows:—

Zircon .. . . .	36.6%
Ilmenite .. . . .	31.3%
Rutile .. . . .	23.0%
Other minerals .. . . .	9.1%

The main differences between the concentrates obtained from the sandstones and the natural beach concentrates are the smaller degree of rounding in the former, and the higher percentage of monazite, epidote, staurolite, hornblende and pyroxenes.

The occurrence of heavy minerals in the Triassic sandstone near Sydney and the Upper Coal Measure sandstones near Muswellbrook leaves little room for doubt as to the origin of the concentrates on the beaches between Newcastle and the mouth of the Shoalhaven River. It is suggested by analogy, that the beach sand concentrates on the North Coast have been derived from the Triassic Series of the Clarence River District. The writer has not yet had an opportunity of preparing a concentrate from the Clarence River sandstones, but the preparation and examination of such a concentrate should prove whether the beach concentrates on the North Coast have been derived from this source.

The origin of the gold and platinum in the beach sand concentrates is, however, still in doubt. As the amounts of concentrates obtained from the sandstones were too small to allow of assays for gold and platinum being carried out, it is not known whether these metals are present in the Triassic sandstones. It is suggested that the gold and platinum must be regarded as local additions to the zircon-ilmenite-rutile concentrate, as they only occur at a few



localities along the coast, whilst the zircon-ilmenite-rutile concentrate has a very wide distribution.

#### Acknowledgments.

The writer's best thanks are due to Mr. D. H. Newland, State Geologist, of New York, for assistance in the identification of certain minerals present in the sands examined, and to Mr. M. Morrison, Curator of the Mining Museum, Sydney, for information regarding the occurrence of the deposits of heavy mineral concentrates on the beaches of the North Coast of New South Wales.

#### REFERENCES.

References to the occurrence of the North Coast beach sand concentrates will be found in the following:—

Annual Report, Department of Mines, N.S.W., 1895. Report by J. E. Carne.

Bulletin No. 13, Department of Mines, N.S.W., by H. G. Raggatt, B.Sc.

Journal of the Royal Society of N.S.W., 1892. Report by J. C. H. Mingaye.

THE CELLULOSES OF TWO WATER PLANTS,  
*OTTELLA OVALIFOLIA* (RICHARD) AND  
*EICHORNIA CRASSIPES* (SOLMS).

By JOHN CAMPBELL EARL, D.Sc., Ph.D.,  
AND THELMA MURIEL REYNOLDS, M.Sc.

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(Read before the Royal Society of New South Wales, June 3, 1931.)

Apparently celluloses from most sources are identical. One notable exception is the cellulose of *Posidonia australis*, and a preliminary examination (Arneman and Earl, this Journ., 1929, 63, 44) indicated that another water plant (*Potamogeton* sp.) might possibly prove to differ from the usual standard in respect of its cellulose.

The present communication deals with an attempt to compare the celluloses of two water-plants, which were available in quantity, with the standard, cotton cellulose. In comparisons of this kind, a difficulty always met with is that of preparing a product which can reasonably be regarded as a pure cellulose. The two plants examined, *Ottelia ovalifolia* and *Eichornia crassipes*, proved to be no exception to the general rule. When a number of the recognised methods for isolating celluloses were applied to these plants, products were obtained which yielded triacetates whose optical rotations differed widely from the accepted standard of  $[\alpha]_D = -21$  to  $-22^\circ$  of cotton cellulose triacetate. It was apparent, however, that the

employment of these methods had not led to the isolation of "pure celluloses," since certain supplementary treatments profoundly modified the properties of the products, eventually bringing them much closer to the standard.

The following four methods were adopted:—

(1) The washed leaves were boiled for half an hour with 1 per cent. sodium hydroxide solution. The dark-coloured, finely divided mass was washed well with water and then submitted to the action of chlorine gas, after which it was again washed with water and extracted with boiling alcohol. The chlorination and extraction with alcohol were repeated.

(2) (Cross and Bevan's method.) The washed leaves were boiled with 1 per cent. sodium hydroxide solution and chlorinated as in method (1). After washing, the chlorinated material was immersed in a cold 2 per cent. solution of sodium sulphite, which was then heated to boiling for two or three minutes. After filtering and washing the chlorination and extraction were repeated.

(3) After the initial alkaline treatment, the material was boiled for  $1\frac{1}{2}$  hours with 2 per cent. sulphuric acid, before chlorination and extraction with sodium sulphite as in method (2).

(4) (c.f. Link, J.A.C.S. 1929, 51, 2506). The air-dried leaves were shredded and extracted in a Soxhlet apparatus for 24 hours with 95 per cent alcohol. After removal of the solvent by a current of dry air, the material was further extracted for 26 hours, with 99 per cent. alcohol. It was again dried, and was then extracted for 26 hours with benzene. At this stage the material was ground in a corn mill and passed through a 30 mesh sieve. After washing with hot water it was allowed to remain for 29

hours, with occasional stirring, in contact with 1 per cent. ammonia solution. After washing with water a further 17 hours treatment with 1 per cent. ammonia solution was applied. The material was then chlorinated and treated with sodium sulphite as in method (2).

Methods (1) and (2) yielded products from which considerable quantities of furfural could be obtained by distillation with 12 per cent. hydrochloric acid. A supplementary extraction with 2 per cent. sulphuric acid, as applied in the case of *Posidonia* (J. Chem. Soc. 1923, 123, 3223), caused a loss in weight of 30 to 40 per cent., which was not repeated on further extraction. In the case of *Ottelia* cellulose a prolonged treatment (10 hours) with boiling 12 per cent. sodium hydroxide solution was found also to bring about a loss in weight of over 50 per cent.

The celluloses obtained by the various means were compared as before, (Arneman and Earl, loc. cit.) by determining the optical rotations of the triacetates prepared by Barnett's method.

Since there is always the possibility that any chemical treatment applied to a cellulose may bring about a certain amount of break-down of the molecule, it was considered advisable to determine the viscosities of solutions in chloroform of each of the triacetates under examination. A marked lowering of the viscosity might be interpreted as indicating molecular degradation. It should be noted, however, that the values given indicate merely flow-times in a particular viscometer, and can in no way be regarded as absolute, reproducible results.

The results obtained are summarised in the following table, values for wheat-straw and cotton celluloses being inserted for comparison purposes:—

TABLE I.

Material.	Method of Extraction.	Cellulose Triacetate.		Triacetate from acid-treated Cellulose.		Triacetate from alkali-treated Cellulose.	
		$[\alpha]_D^{14.17^\circ}$	Viscosity*	$[\alpha]_D^{14.17^\circ}$	Viscosity*	$[\alpha]_D^{14.17^\circ}$	Viscosity*
<i>Ottelia ovalifolia</i> ..	1	-3.9	163	{ -16° -16.75°	72	-21.5°	96
<i>Eichornia crassipes</i> ..	1	-6.4	164	-15°	77	—	—
" " ..	2	-10	113	-16.25°	68	—	—
" " ..	3	{ -16.25 -18.5	94	—	—	—	—
" " ..	4	-20.4	78	—	—	—	—
Wheat Straw ..	2	-33.75	99	-25°	89	—	—
Cotton ..	—	-21.4°	136	-20.5°	65	—	—

\* Time of flow in seconds of a 0.8 per cent. solution in chloroform at 20°C.

Variations in the application of the acetylation method have little effect on the optical rotation of the triacetate of cotton cellulose, but, in general, the longer the duration of the operation, the lower the viscosity of the triacetate produced. Treatment of cotton cellulose prior to acetylation with 1 per cent. sulphuric acid at 90°C for one hour lowered the viscosity of the triacetate considerably, and repetition of the treatment caused a slightly greater lowering. In this comparison, summarised in Table II, the triacetates were prepared under carefully standardised conditions.

TABLE II.

Material	Triacetate	
	$[\alpha]_D^{16^\circ}$	Viscosity
Untreated cotton cellulose	-21°	436
Treated once with acid	-19.7°	181
Treated twice with acid	-19.3°	153

\* Time of flow in seconds of a 2 per cent. solution in chloroform at 25°C.

It is probable, therefore, that in the water-plants under examination, the celluloses are identical with cotton cellulose. The inevitable association of other materials with

the celluloses, prevented "pure celluloses" from being isolated, and the acid treatments resorted to caused some molecular degradation with a consequent lowering of both optical rotation and viscosity of the final cellulose triacetates.

Thanks are due to Science and Industry Endowment Fund for a contribution towards the expenses of this investigation.

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## PHYSIOGRAPHY OF THE BATHURST DISTRICT OF NEW SOUTH WALES.

By C. A. SUSSMILCH, F.G.S.

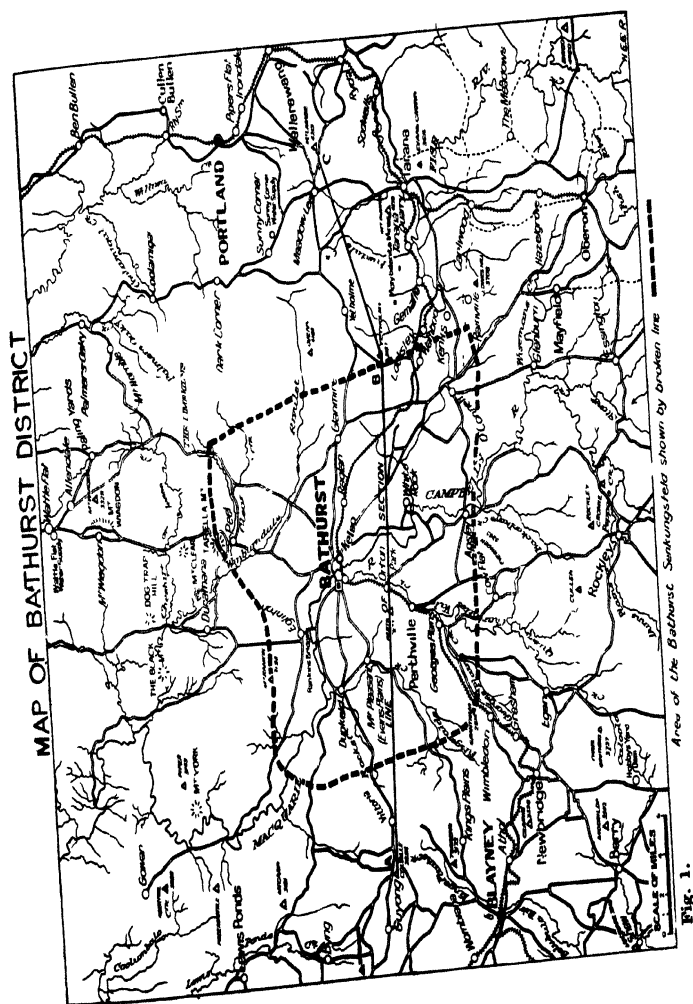
(With Plates I and II and two Text Figures.)

*(Read before the Royal Society of New South Wales, July 1, 1931.)*

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The region referred to in this paper occurs in the State of New South Wales immediately to the west of the Blue Mountain tableland. It includes the eastern part of the County of Bathurst, the south-western part of the County of Roxburgh and the north-western part of the County of Westmorland. Where these three counties meet there lies the city of Bathurst, approximately in the centre of the region to be described. The main western railway line traverses the centre of this region from east to west.

That part of this region which in this paper is called the Bathurst Senkungsfeld is an approximately rectangular area with its longer axis about 22 miles in length, lying in a north north-western direction; its east-west axis is about 19 miles in length. This region has a general elevation of about 2400' and is surrounded on all sides by higher tablelands; its approximate extent is shown on the map --Fig. 1. To the north, west and south-west lies the Orange tableland with a general elevation of about 3100'. To the east lies the Mt. Lambie tableland (the western portion of the Blue Mountain tableland) with a general elevation of about 4100', while to the south-east lies the Oberon tableland with an elevation of about 3600'. The junction between the Bathurst Senkungsfeld and the surrounding tablelands is always a well-marked scarp, the





change in elevation between it and its surroundings being everywhere an exceedingly abrupt one. The surface of the Bathurst Senkungsfeld is, in all its main topographical features, essentially similar to that of the surfaces of the higher surrounding tablelands and these will now be described in detail.

1. *The Bathurst Senkungsfeld.*—Owing to its gentle topography this region is frequently referred to as the Bathurst Plains. This name is, however, a misnomer, as the surface is not a plain but consists of a series of broad, rounded ridges separating moderately wide, shallow, aggraded valleys. The ridges rise to a general elevation of about 300' above the flood plains of the valleys, and the tops of these ridges represent a peneplained surface cut out of the granite and associated strata during the earlier part of the Tertiary Period. The rock underlying this region, except for a few small areas near its margin, consists entirely of granite of a moderately acid variety; it is exceptional, however, to find outcrops of this granite in the Senkungsfeld proper neither in the stream channels nor on the ridges. Everywhere the ridges are mantled with a thick accumulation of weathered granite, while the valley floors are covered with a thick deposit of alluvium. The railway cuttings show the granite to be completely weathered to depths of upwards of 20 feet. Nowhere within the confines of the Senkungsfeld are the main streams actively eroding their channels. All the stream channels are aggraded. The whole of these features suggest an old and thoroughly mature topography.

This region is drained by the Macquarie river and its tributaries; the Macquarie river, here known as the Fish river, enters the Senkungsfeld at the south-east corner near the township of Tarana, where it emerges from a

deep valley cut into the Oberon tableland; from here it flows in a general north north-west direction in a broad, shallow valley with an extensive flood plain (see Fig. 3) until it reaches the north-western corner, where it immediately enters a gorge 1000' deep cut into the Orange tableland. So wild and rugged is the valley of the Macquarie river beyond this point that no road follows it for any distance in this direction and to reach settlements lower down the river, one has to take a roundabout course over the Orange tableland.

The surface of the Bathurst Senkungsfeld is not definitely level but appears to be tilted upwards to some extent towards the bounding fault scarps at certain localities. In the neighbourhood of Bathurst the general level of the peneplain is 2400' but along its eastern margin notably round about Wambool railway station, the general level is about 2550' to 2600'.

At its south-western corner this tilting is particularly marked where the railway ascends from the Bathurst Senkungsfeld to the Orange tableland, but is quite absent further to the east, where the road from Bathurst to Rockley crosses the scarp.

Rising above the general level of the Bathurst Senkungsfeld are the Bald Hills, a group of isolated hills in the neighbourhood of Bathurst, whose highest point reaches an altitude of 2852', that is about 500' above the general level and 700' above the Bathurst railway station. The highest of these hills is capped with basalt about 200' thick and underlying this there is a bed of alluvial wash about 15' thick, which in turn rests upon granite. These hills represent a residual of the older tableland out of which the peneplain, which forms the surface of the Bathurst Senkungsfeld, has been eroded. It corresponds

to similar residuals which occur on the Orange Tableland, such as The Brothers, 3737' in altitude, which will be referred to in the next section. Similar basalt-capped residuals also occur, rising above the Blue Mountain Tableland, such as Mt. Tomah, Mt. King George, etc., all about 500 to 550 feet above the general peneplain level in this region.

2. *The Orange Tableland.*—This has a general altitude of about 3100'. Its surface is not flat but consists of a series of broad, mature, aggraded valleys separated from one another by well rounded ridges, the latter all rising to a general level of about 3100'. The following is a list of the trigonometrical stations occurring in the region whose altitudes are available:

Evenden . . . . .	3245'
Rockley . . . . .	3050' (approx.)
Torrens . . . . .	3173'
Colville . . . . .	3286'
McCann . . . . .	3181'
Aberfoyle . . . . .	3036'
Piper . . . . .	3149'
Rankin . . . . .	3198'
Merrions . . . . .	3222'
Wyagdon . . . . .	3328'
Tambaroora . . . . .	3124'

These are all on the peneplain level, some few of them rising slightly above it.

This 3100' level represents the surface of a great peneplain, developed during the early part of the Tertiary period, not only in this region but throughout the eastern part of New South Wales. The villages of Millthorpe (3131') and Spring Hill (3087') are situated on this level.

Rising above this level there are some higher hills, such

as The Brothers, three isolated hills in the parish of The Brothers, the highest of which is 3737' in altitude. Other higher points are Moorilda Trig. Station, 3502' in altitude; Clarke Trig. Station, 3578' in altitude; and Mt. Macquarie, 3943' in altitude. These are residuals of an older tableland out of which the above-mentioned peneplain has been cut. Near the township of Orange is an important group of still higher hills called the Canoblas Mountains, the highest of which reaches an altitude of 4576'. These latter are not residuals of the older tableland but are a group of extinct volcanoes built up on the peneplain surface late in the Tertiary period.

The broad, mature valleys already referred to average about 300' in depth below the tableland surface and are all well aggraded. They have been cut out of highly inclined lower palaeozoic strata as well as in places out of Tertiary basalts. The town of Orange (2846') lies in one of these mature valleys, as also does the town of Blayney (2844').

Mature valleys of this kind occur throughout Eastern Australia wherever undissected portions of the uplifted Tertiary peneplain still survive; they occur at all altitudes according to the amount of uplift which has taken place; they have been referred to by Mr. E. C. Andrews<sup>1</sup> as the "Upland Valleys," and are considered to have been formed late in the Tertiary period, before the uplift of the present tablelands.

Such streams as flow from the Orange tableland on to the Bathurst Senkungsfeld are in the higher tableland entrenched in youthful valleys. The youthful nature of these valleys changes very suddenly into mature valleys where they leave the scarp which separates the higher from the lower tableland. As already mentioned, this Orange

tableland lies to the west of the Bathurst Senkungsfeld and swings round its northern side, where it joins on to the Hillend-Hargreaves tableland, which has a similar elevation and which is in fact an eastern continuation of the Orange tableland. It also borders it on the south-western side, where it joins up with the Oberon tableland. From this latter, however, it is separated by a definite scarp, marking a change from a 3100' elevation to a 3700' elevation.

Throughout the Orange tableland the underlying rocks consist mainly of highly inclined Ordovician and Silurian strata, mainly slates, limestones and tuffs. These rocks, as compared with the granite underlying the Bathurst Senkungsfeld, are weak structures. Overlying these lower palaeozoic strata there is in places, particularly round about the town of Orange, a thin veneer of Tertiary basalt 200' to 300' in thickness.

3. *The Mt. Lambie Tableland.*—This lies to the east of the Bathurst Senkungsfeld and has a general elevation of about 4100'. The following are some of the trig. stations in this region: Mt. Lambie, 4219'; Mt. Tarana, 4178'; Ovens trig. station, 4164'. The rocks in this tableland consist mainly of lower palaeozoic strata of Silurian and Devonian age, including quartzites, slates, limestones, clay stones and tuffs. There are also some considerable areas of granite, particularly round about Yetholme, part of the same bathylith which underlies the Bathurst Senkungsfeld. The Devonian quartzites are very resistant rocks, but they do not cover a very large area, and the rocks of the region as a whole are not of a resistant character. Owing to its higher elevation, particularly as compared with the Bathurst Senkungsfeld, this region has undergone considerable dissection during the present cycle of erosion,



Fig. 3

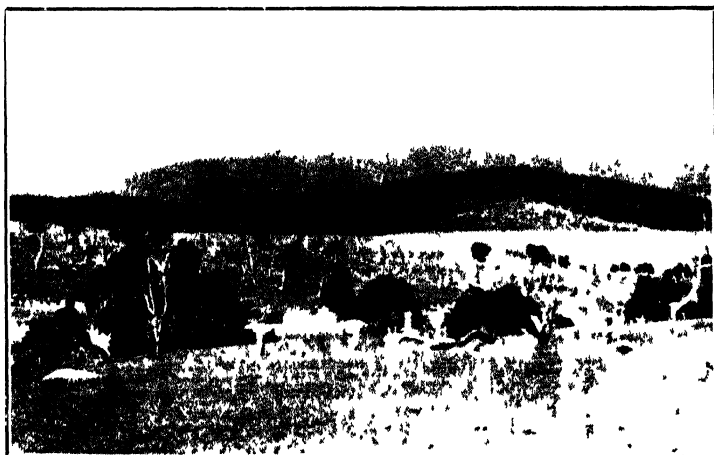


Fig. 4.



the lower block forming a temporary base-level of erosion for the higher block, but some remnants of the original peneplain surface still remain and these display similar surface features to those of the Orange tableland. Immediately to the east of the village of Yetholme some of the characteristic "upland valleys" occur 300' below the general level of the tableland and Tertiary basalt is found similar to that occurring near the town of Orange. Such streams as drain from this area westwards into the Bathurst Senkungsfeld are entrenched in deep, rugged gorges. This Mt. Lambie tableland is really the western margin of the Blue Mountain tableland, the whole having a definite tilt towards the east. The whole of this region will be described in more detail in a later paper.

4. *The Oberon Tableland.*—This occurs at the south-eastern margin of the Bathurst Senkungsfeld and is really a slightly down-faulted portion of the Mt. Lambie tableland (here known as the Jenolan tableland). Its general altitude is about 3700' and its geological structure and topography are essentially similar to that of the Orange tableland.

5. *Fault Scarps.*—The change in elevation from the lower Bathurst Senkungsfeld to the higher surrounding tablelands is remarkably abrupt, the margins everywhere being marked by a steep scarp separating the lower and higher tablelands. It is suggested that these scarps are all tectonic scarps. The most prominent of the scarps is that which forms the western margin of the Mt. Lambie tableland, the latter having an altitude of about 4100' as against an altitude of 2400' of the Bathurst Senkungsfeld. The scarp here is not a simple one. As one travels eastwards from Bathurst there is first a very steep rise on to a bench a few miles wide with an altitude of about 3000' (Plate I, Fig. 4). The Yetholme trig. station, with an altitude of 3157', lies on



this bench (Plate II, Fig. 5). From here there is another very abrupt rise to the Mt. Lambie tableland. This rise is not very noticeable on the main road, because this follows a valley cut in the higher tableland. The western margin of the Mt. Lambie tableland therefore appears to be marked by step-faulting, the first fault, which might be called the Yetholme fault, having a throw of about 1000' to the bench on which the Yetholme trig. station stands (Plate II, Fig. 6), the second one, the Wambool fault, having a throw of about 550', the two faults having a combined throw of from 1500' to 1600'. The narrow bench between the Wambool and Yetholme faults has been very much dissected (Plate I, Fig. 4) and in places has been very largely removed, particularly where the main streams emerge from the Mt. Lambie tableland on to the Bathurst Senkungsfeld. In some places, notably near Wambool, large valleys have been cut along the line of the Yetholme fault and have thus partly isolated the lower 3000' bench from the higher Mt. Lambie tableland.

The scarps which mark the junction of the Bathurst Senkungsfeld with the Orange tableland, although not so high, are just as pronounced and are probably also due to faulting, the throw of the fault here being about 700. It is quite possible, however, that along this western margin warping may have taken place to a considerable extent, as has previously been pointed out in the south-western corner where the railway line ascends the scarp, so that the scarp here may be due to (a) faulting (b) monoclinal folding, or (c) a combination of both; whichever of these is correct, the fact remains that the scarp is primarily a tectonic one.

At present the writer can present no direct geological evidence of the existence of these faults. Owing to the



Fig. 5



Fig. 6.



# BATHURST DISTRICT N.S.W.

Section on line A,B,C

Horizontal Scale 2 miles to an inch Vertical Scale 2000 feet to an inch

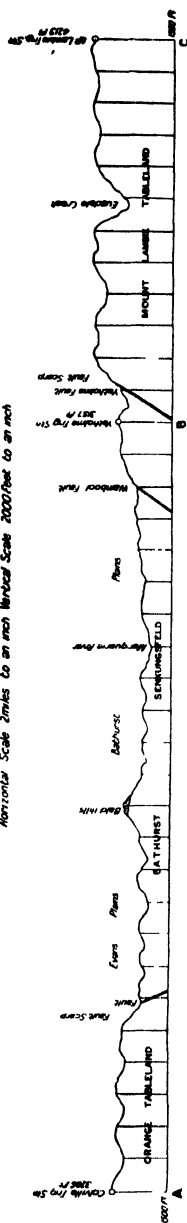


Fig. 2.

East-west section across the Bathurst Senekungfeld.

complex geological structure, such evidence could only be obtained by the preparation of a detailed geological map of the whole region and the existence of these faults is suggested therefore from purely physiographic evidence.

If this suggestion with regard to faulting is correct then the Bathurst region is a typical Senkungsfeld or "Sunk Land," as originally suggested by Mr. E. C. Andrews.<sup>2</sup> It is not suggested, however, that it actually subsided but that during the elevation which brought the present tablelands into existence this particular region lagged behind during the uplift and was therefore not uplifted to such a great height as the regions immediately surrounding it. The absence of lake-deposits on the lower block indicates that the differential movement must have been a relatively slow one, the Macquarie river cutting down its gorge in the Orange tableland block as fast as the latter was elevated with respect to the Bathurst block. The physiographic evidence in support of the faulting is as follows:

a. The topography of the surface of the Bathurst Senkungsfeld is in a similar stage of development to that of the higher surrounding tablelands.

b. While active erosion is being carried on by all the main streams in the surrounding tablelands, no such erosion is taking place to-day by these streams where they cross the Bathurst Senkungsfeld.

c. The streams which enter the depressed region have youthful valleys in the higher blocks and the Macquarie river, where it leaves the depressed region, leaves it by means of an almost impassable gorge; within the Senkungsfeld itself, however, the valleys of all the streams are thoroughly mature, the main stream channels being heavily aggraded; this is particularly the case with the

Macquarie River itself, which has extensive flood-plains in the neighbourhood of Bathurst.

d. The scarps which separate the Bathurst Senkungsfeld from its surroundings are exceedingly steep and abrupt. They follow fairly straight courses, and no spurs extend from them into the lower region.

e. These scarps all display a very youthful topography as compared with the surfaces of the tablelands above and below them.

It might be argued that this relatively low-lying region is due to differential erosion in weaker rocks. In the authors' opinion the granite underlying this depressed region is not a weak structure as compared with the geological structure of the surrounding tablelands; but is relatively resistant. In the higher tablelands, notably the Mt. Lambie Tableland, there are some belts of very resistant quartzites, but these latter are quite limited with regard to the area they cover as compared with the very extensive development of weak Ordovician and Silurian rocks (mainly slates), which occupy the greater part of the surrounding tablelands. Some parts of the scarp on the eastern and north-eastern sides of the depressed region consist of the same granite as underlies the Bathurst Senkungsfeld, and it extends for some distance back into these higher tablelands. Where this granite occurs on the sides of the higher tablelands, as, for example, from Yetholme to Tarana, outcrops are numerous, whereas such outcrops are exceedingly rare in the lower depressed region, and in this depressed region the granite is everywhere very deeply weathered.

Dr. W. R. Browne<sup>3</sup> has suggested that, under conditions of low physiographic relief, deep and thorough decomposition of the surface rocks may be effected in the case

of such igneous rocks as granite to depths of 400' or more, whereas this action would not take place to any notable depth in the ordinary sedimentary rocks. He states -

"If now we imagine a region, which has for long been in the last stages of a cycle of erosion, to undergo uplift so that the peneplain or low-level region of very mature topography and of heterogeneous rock composition becomes a plateau, the new and the rejuvenated streams will attack the more deeply and thoroughly decomposed rock masses, leaving the less decomposed masses in relief. The differential rate of erosion is thus at first dependent not on the relative resistance of the various rock units to mechanical weathering and erosion so much as on the differential yielding to antecedent deep weathering."

He states further—

"If we now take the case of a chemically weak but mechanically resistant rock like granite, during the uplift following peneplanation, it would rapidly erode to the lowest level of decay, that is to its former water-table level. Thereafter erosion of the granite, though not entirely stopped, would proceed with extreme slowness and a kind of temporary base level of erosion would be established."

Could such a process as this account for the physiographic features of the Bathurst district? What the present writer has called the peneplain level of the Bathurst District is here 700' below the corresponding level of the Orange Tableland, so that we would have to assume that, just before the uplift which produced the present tablelands, the granite over the Bathurst area was decomposed to a depth of at least 700', but as no solid granite has been exposed at the present time even in the base of the existing stream channels, which are 300' below the peneplain level, the depth of decomposition of the granite would have had to be at least 1000', which seems to be an unwarranted assumption in this particular case. A deep valley has been developed in the granite of the higher Mt. Lambie Tableland by Solitary Creek, one of the tributaries of the Macquarie River, during the present cycle of erosion, i.e., since the peneplain was up-

lifted; but this valley is no more mature than the valleys of other tributaries of the Macquarie River, cut out of the sedimentary rocks of the Orange Tableland. In both cases the surface of the Bathurst Senkungsfeld is acting as a temporary base level of erosion for the tablelands drained by these streams.

Differential erosion of the nature suggested could not explain, in the writer's opinion, the wonderfully regular system of mature ridges and "Upland Valleys" developed on the surface of the Bathurst Senkungsfeld, which so closely parallel those on the adjoining Orange Tableland, 700' higher, and which also compare just as closely with similar features on the granite tablelands of other parts of New South Wales where the peneplain surface is still undissected.

The fact that the borders of the Bathurst Senkungsfeld to a very large extent correspond to the boundaries of the Bathurst granite bathylith would seem to indicate that the junction of the bathylith with the surrounding sedimentary rocks was a line of weakness, and that during the uplift which produced the present tablelands, the bathylith as a whole tended to lag behind, displacement and consequent faulting taking place along the junction.

As compared with other Senkungsfelder, the Bathurst example is somewhat unusual both with regard to its shape and its actual size; as previously stated, it measures about 22 miles by 19 miles, and is therefore nearly square in shape. With regard to size, some smaller examples occur in the United States as described by W. M. Davis.<sup>4</sup> One of these is Deep Spring Valley in the Inyo Mountains on the border of the States of California and Nevada; its dimensions are 12 miles by 5 miles, and its surface is from 1000' to 3000' below that of the surrounding highlands.



Another example is the Salina Valley in the same region, which measures 25 miles by 10 miles, the mountains on one side of its rising 6000' above its surface.

The Sydney Senkungsfeld of New South Wales is somewhat larger, its dimensions being about 40 miles long by 20 miles wide.

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#### EXPLANATION OF PLATES.

##### Plate I.

Fig. 3.—Valley of the Macquarie River at Bathurst The ridge in the middle distance rises 300ft. above the flood plain. The Mt. Lambie tableland is faintly shown on the sky line.

Fig. 4.—View looking east from the Bathurst Senkungsfeld towards the Mt. Lambie tableland. In the foreground are the mature valleys and ridges which characterise the surface of the Bathurst Senkungsfeld. In the middle distance is the 3,000ft. bench partly dissected. In the background is the fault scarp which forms the western margin of the Mt. Lambie tableland.

##### Plate II.

Fig. 5.—View of the Mt. Lambie tableland looking north-north-east from the Bathurst-Tarana road. On the sky line

to the left is the 3,000ft. bench, and to the right the higher Mt. Lambie tableland.

Fig. 6.—The Yetholme fault scarp immediately to the north of the Bathurst-Yetholme road.

ON A SPECIMEN OF FOSSIL TIMBER  
FROM THE  
SYDNEY HARBOUR COLLIERY.

By R. T. BAKER.

With Plates III-VI.

(Read before the Royal Society of New South Wales, Aug. 5, 1931.)

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**Introduction.**

This specimen was discovered by Mr. D. Scully in this mine in 1898 at a depth of 2,225 feet, and noticing distinct, white markings radiating from the pith, much resembling medullary rays, he was under the impression that it was an "Oak"—a vernacular name applied in Australia to the species of the Genus *Casuarina* of the Natural Order, Casuarinæ. A microscopical examination showed, however, that these white markings are due to the presence of calcium carbonate as explained below.

The attention of the author was drawn to it by an article written by Mr. Scully on fossils, in which he referred to this "find" under the name of "Oak," and states that when he arrived at the surface the whole specimen had been appropriated.

At the time of the "find" Mr. J. L. C. Rae was the manager, and he procured a piece, which he very kindly presented to the author, in order that a scientific investigation might be undertaken, and for which kindness the author herewith expresses his gratitude. However, sufficient sections for microscopical examinations were obtained without destroying the facies of the specimen, leaving two-thirds of the original complete in the circumferential area.

Mr. Rae states that "it was found in a band of hard, greenish, micaceous sandstone which extended from a depth of 2,219 feet to 2,322 feet; the broken off ends remaining in the wall of the excavation on each side of the shaft at practically its full diameter, so that the total length of the fossil stem procured was about 20 feet."

Its original shape is excellently preserved, showing that it had not been subjected to any crushing strain, or if it had, the coating of calcium carbonate had enabled it to resist such pressure.

#### General Description of the Specimen.

The piece of fossil timber upon which this research is founded, was sawn off when the log came to the surface. It is almost circular in form, measuring in the longer axis  $3\frac{1}{4}$  inches, and in the shorter one,  $2\frac{3}{4}$  inches, and  $1\frac{1}{2}$  inches in thickness (Plate III., Figs. 1 and 2). Both faces had been polished. In Fig. 1 it is shown in perspective, whilst Fig. 2 gives a front view of the transverse section showing the two kinds of material of which it is composed, viz.: the dark, black, inner portion, being the fossilized timber, and the outer, pale coloured band composed of calcium carbonate.

No bark has been preserved; the black substance on the outer edge is not that material, but portions of tracheids displaced by the calcium carbonate. The pith is not in the centre of the wood, but its position is indicated by the small white spot towards the upper left of the centre; the annual rings are not seen in this surface. The rings of white spots are calcium carbonate in the tracheids, or canals in transverse section of this substance.

No oil or turpentine cells, canals, channels or passages were found throughout the xylem material examined.

That portion of the wood between the nearest part of the circumference and the pith, represents the slow growth of the stem, whilst in the opposite axis to this, the quicker growth, due to the external conditions of cold and warmth respectively. From this view of the specimen it is seen that the calcium carbonate deposit is most pronounced on the cooler side of the tree's environment, and gradually peters out at the extremities exposed to the warmer conditions that prevailed during the life of the tree. The same substance occurs in the pith.

To the top, left and right of the pith (Plate III., Fig. 2), are shown two white radial lines; these are channels conveying the calcium carbonate from the vertical canals of the xylem, to be deposited on the exterior of the stem, in the form of columns seen in transverse sections (Plate IV., Fig. 3), in which figure can also be seen to the right and also lower left of pith, rays filled with calcium carbonate.

#### **Description of the Timber Structure.**

This portion of the specimen is particularly well preserved, scarcely an organ of structure being wanting to enable it to be systematically described. The central column or pith has almost entirely been replaced by calcium carbonate, and only a few spiral vessels and parenchyma tissue have been preserved in that part of the stem or primary xylem and in juxtaposition to that mineral. Xylem parenchyma is entirely absent.

##### *(a) Transverse Section.*

The tracheal structure is uniform throughout the primary and secondary xylem area.

The annual rings are well marked (Plate IV., Fig. 3, and Plate V., Fig. 5), the dark autumn growth being quite prominent, and producing a distinct line of demarcation



Fig 1

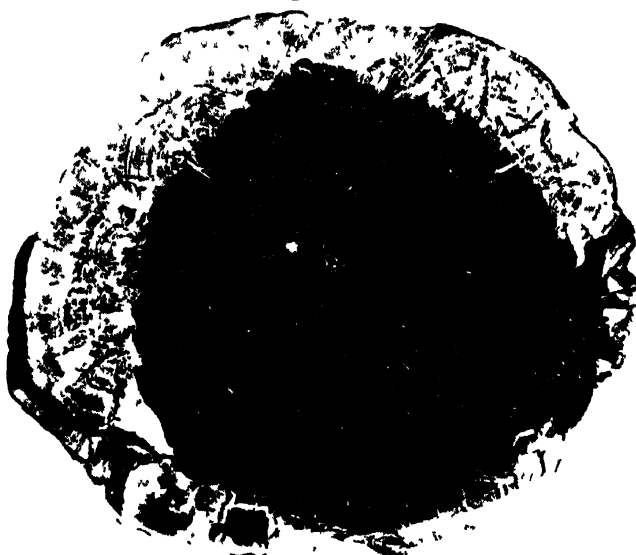


Fig 2





Fig. 3.



Fig. 4.





between it and the spring growth, and these number about six—the approximate age of the tree—the two outer ones being half an inch apart, thus indicating that the tree was a rapid grower for its age, and height of stem. The others gradually lessen in width towards the centre, whilst one or two seem to peter out and so do not complete the circle.

The medullary rays are very numerous, fine, and more often than not, are filled with calcium carbonate, and so probably acting as ducts to convey that substance from the pith to the vertical channels or to the outer surface of the stem.

The tracheids as seen in section, show great variety of shape, ranging from triangular to circular or rectangular, but mostly are irregularly hexagonal or pentagonal. The rows of tracheids vary in number between the rays, from a few, up to 25 or even over 30. Only in just a very few tracheids was a very pale brown deposit detected (vide remarks under radial section).

(b) *Radial Section.*

The medullary ray parenchyma, like the rest of the structure, is well preserved, and is characterised by thin walls in which, on the radial surface, are pitted cells varying in number between each tracheid, but mostly there are two of these cells, with an oblique slit.

On the radial walls of the tracheids, are well formed and prominent bordered pits, in all instances in uniseriate rows the full width of the lumen, circular in shape, not adpressed, and with a circular depression in the centre. No bars of Sanio were seen. This feature is in accord with what obtains in the Australian Genus *Callitris*, and so, in this feature at least, shows no connection with the Australian Genera *Araucaria* and *Agathis*. They can be seen in Plate V., Fig. 7, and more prominently so in the more

highly magnified Plate V., Fig. 8. In the centre of Plate V., Fig. 9, the walls of the tracheids appear to be broken, but this feature is due to bordered pits on the tangential walls being cut in section.

These bordered pits occurring in the tangential walls (Plate V., Fig. 10), are a very unusual feature in Conifers.  
(c) *Tangential Section.*

The end-on view of the medullary rays (Plate V., Fig. 10), shows how numerous they are. All are uniseriate, varying in number of divisions from a few up to a dozen or more, and generally are filled with calcium carbonate. The unique feature of this section is the presence of uniseriate rows of bordered pits in the tangential walls similar to those shown in Plate V., Fig. 8.

#### Calcium Carbonate.

As stated above, in a cross section the specimen is seen to consist of two well defined substances, i.e., the black part comprising the fossil timber, and the outer, broad, light coloured band composed of a number of well defined concentric accumulations.

An analysis of this material, as given below, showed that it is almost completely composed of calcium carbonate.

Calcium carbonate . . . . .	96.000%
Magnesium carbonate . . . . .	0.005%
Oxides of Iron and Aluminium ..	3.720%
Silica . . . . .	0.268%

Nor is it restricted to the exterior of the wood, but is found also to permeate or occur in the pith channels or canals radiating from this centre through the xylem to the exterior surface (Figs. 2, 3, 4, 12, 13), and also in vertical canals of varying diameters, and it is from these that the exterior deposit of calcium carbonate obtained its supplies.

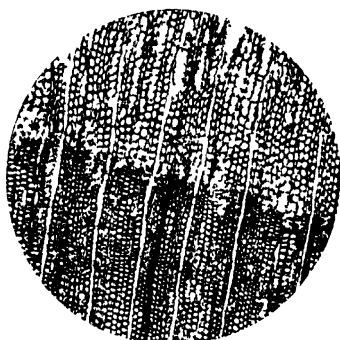


Fig. 5

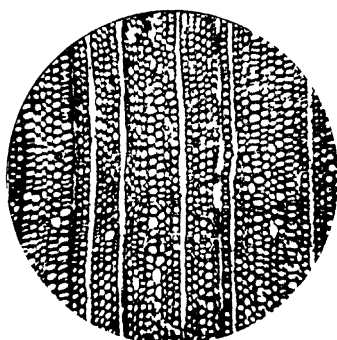


Fig. 6.



Fig. 7.



Fig 8



Fig. 9.



Fig. 10.





Fig 11



Fig 12

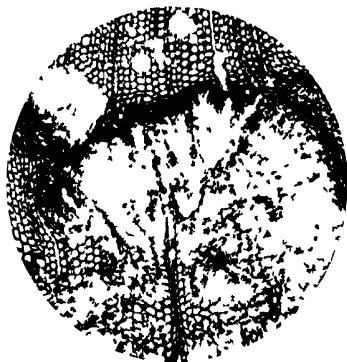


Fig 13.



Fig 14



Fig. 15.



Fig 16.



In Plate III., Fig. 2, and Plate IV., Fig. 4, it is shown to occur as small white spots in concentric circles around the pith, and on a high magnification shows a coalescence, and thus forming portions of a ring. Plate IV., Fig. 3, shows a number of vertical canals of calcium carbonate, connecting with a horizontal canal conveying this mineral to form a concentrically built column at the top right outer edge of the xylem, and in so doing, it may be noted that it has pushed out at least two or three rows of the tracheids of the last annual ring. The one on the right is displaced very much more so. Just above the pith are three smaller vertical canals in section, and to the left of the pith is a cluster of these, the inner ones forming a ring.

This plate also shows the well defined annual rings. Plate III., Fig. 2, illustrates a cluster in cross section of the concentrically built columns of calcium carbonate on the exterior surface of the stem, the curved narrow black bands removed from their centres are displaced xylem tracheids, whilst Plate VI., Fig. 15, shows in the centre a cluster of removed tracheids producing a tessellated effect.

Plate VI., Fig. 13 shows a transverse section of a vertical canal with calcium carbonate as it was received from the tracheids, the central supply being indicated by the radiating lines, from the two rows of compressed tracheids which very much resemble the transfusion tissue which supplies silica to the leaves of Dicotyledoneous plants. The dark boundary is composed of displaced tracheids. Plate VI., Fig. 14, is a vertical section showing that these features are truly canals—the whole of the white body.

These exterior columns of calcium carbonate are eventually backed by a mass of crystalline carbonate of lime, in which also are found detached pieces of tracheids (Plate III., Fig. 2, and Plate VI., Fig. 15).



Now, in view of Newton's statement in his *Principia* Rule I. . . . "That Nature does nothing in vain," one naturally asks, then, for what purpose or object was this substance built up by the tree, for it would be put there to serve some object in its life history.

One is hardly justified in looking upon it as a valueless, physiological structure, but rather as one of great importance to its very existence.

Warming, in his "*Etudes sur la famille des Podostemaceæ*"—plants of which Natural Order all grow in swiftly flowing rivers and streams, and which, therefore, require to be specially protected against the shearing action of the violently agitated water, believes that Silica cells and Silica corpuscles play a mechanical part in the life of plants of this Natural Order.

It is universally accepted that the Coal Measures were laid down in water—stagnant most probably—and as this tree coated itself with calcium carbonate it may perhaps be inferred that it grew at the inlet or outlet of such water, and thus had to provide itself with a mechanical contrivance to resist "the shearing action of the running water" just as in the case of the *Podostemaceæ*.

And this plan of construction is further supported by its regularity and design for strength, by building this supporting "wall" in columns, and these again protected by an outer layer with a comparatively smooth surface, and so deflecting the oncoming water, or to withstand adverse external climatic conditions.

Man to-day has produced a repique of this handiwork of nature, for the engineer builds similarly when constructing the ends of wharves exposed to heavy seas and gales, little thinking that nature anticipated his designs untold ages ago.

Traumatic deposits they cannot be, for these are laid down without any order or system—just a jumble of exuded substances, as for instance, Kino and Resin.

One can hardly imagine it as a waste product as in the case of calcium oxalate crystals found in the wood of some Dicotyledoneous woods.

This tree had a further physical weakness in that the tracheids would be frail, having bordered pits on both radial and tangential walls—perforations not conducive to strength.

In addition to giving the tree strength, it also served another purpose—protecting it against cold weather conditions, for it is on the side exposed to such that it has its greatest thickness.

Nature has provided the non-Conifers-Dicotyledons, with an organ which serves the mechanical purpose of giving the tree strength, and so in that case there is no necessity to call in the aid of an extraneous substance.

That it was traumatic can hardly be entertained, for it surrounds the whole stem, and also that it was supplied by channels deeply set in the xylem of the annual rings, and even direct from the pith itself. Further, had it been a wound right round the stem it would have had an injury equivalent to the modern method of “ringbarking” a tree, and so died before so heavy a deposit could have been completed.

#### **Manganese Compound.**

A reference is made above of the occurrence of a light brown coloured substance in the tracheids (Plate V., Fig. 6). Now this is the manganese compound first recorded as occurring in the wood of Australian living Conifers by Baker and Smith in “Pines of Australia.” In the many instances of its occurrence, illustrated in that work, it is

always shown as long, cylindrical deposits in both the tracheids and ray parenchyma, but in this wood it occurs in the tracheids only, and as small spherical bodies. This is the first instance, as far as the author knows, of its ever having been recorded in this shape, and further, this is also the first record of this substance occurring in a fossil timber. They are shown in a central tracheid in Plate VI., Fig. 11.

It is quite possible that these indicate a very ancient ancestral feature.

#### DISCUSSION.

The histological characters are so well preserved in the specimen that no difficulty was experienced in systematically placing it as of Gymnospermous origin.

Its homogeneous structure was helpful in working out its differences, affinities, and similarities, from or to described species of fossil timber by the various palæontological authors.

No attempt was made to place it under the heading *Dadoxylon*, a too comprehensive term, in the Author's opinion, in view of our present extensive knowledge of living Coniferous timbers, and was proposed, so the Author was informed, "to include wood having pitted ducts where the wood *may be* equally of the Cordaitan or Coniferous type."

It cannot be placed with the *Cordaite*s, for as Scott states (New Phytologist, Vol. I., 1902), "they are anatomically on the same level as recent Cycads"—a group of plants with which this fossil specimen has little or no connection in its structure, nor has it crowded bordered pits as obtain in that group of plants.\*

\* Jeffrey: Anatomy of Woody Plants, p. 289, pl. 22 & 48.

Again, Scott, in his work "Extinct Plants," p. 149, states: "In the lower Carbonaceous Flora all traces of Cycads are absent, and it is probably from this geological area, in view of the chemical analysis, that the fossil specimen of this paper belongs. Further, the disposition of the bordered pits and other features differentiate the Sydney specimen from the *Pitae*, *Cupressinoxylon* and *Cedroxylon*.

Amongst modern Conifers it certainly differs from *Araucaria* anatomically, and in this respect also from *Dacrydium*, *Podocarpus* and *Agathis*.

Its nearest affinities are with the Genus *Callitris*, both in the arrangement of the bordered pits, nature of tracheids, ray parenchyma, annual rings and presence of the manganese compound, as well as the entire absence of oil canals.

The presence of the calcium carbonate, on the outer surface and in the wood texture, has never yet been recorded as occurring in the wood of any living *Callitris* nor any Australian Conifer. Amongst these, its wood structure more closely resembles that of *Callitris arenosa*, a native of the North Coast of N.S.W. and Southern Queensland.

The presence of the calcium carbonate would appear, according to Geikie and other authors, to place it geologically as from the Lower Carboniferous series, and if this determination be correct, then, according to Scott, *loc. cit. supra*, p. 150, true Conifers have not been previously found, then this Sydney specimen is probably a record of a Conifer from that period.

Seward, in his Fossil Plants, 1917, Vol. III., figures and describes a Coniferous species founded on a specimen obtained from the Priestly Glacier by the Northern Party of Captain Scott's Second Antarctic Expedition, and gives it generic and specific rank under the name of *Antarcticoxylon Priestleyi*.

Now, in comparing the Sydney specimen plates and description with this species it is very noticeable how many features these two specimens have in agreement. Seward states that his specimen was imperfectly preserved (compressed), and so the *primary* xylem is too imperfect to admit of any satisfactory comparison as regards this tissue with other types, and this remark applies to the Sydney specimen; however, almost all the other features are similar, or at least appear so, notwithstanding its having been distorted out of its original protundity. Its chief difference appears to be that it is "a silicified stem," which the Sydney specimen is not, and also having double as well as single rows of pitted cells. "Only single rows were found in the sections examined, although other parts may have double rows," but judging from the diameter of the tracheids, it is very doubtful. Medullary rays are identical in both cases, as well as the secondary xylem.

In describing his species, Professor Seward states: "An interesting feature seen in transverse section of the secondary wood is the occurrence of light bands concentric with the rings of growth, which are broadest near the long axis of the stem. In their narrowest parts these bands are clearly due to partial destruction of the secondary tracheids."

Now that fairly well describes a similar phenomenon in the Sydney specimen, Plate III., Fig. 2, Plate IV., Figs. 3 and 4, for those "bands" or rings correspond to similar rings in the Sydney species, but in this case (seen macroscopically), are composed of separate white bodies, and yet microscopically they are seen in places to be continuous or coalesce, and so perhaps continuity in the Antarctic specimen may possibly be due to the compression to which the specimen had been subjected during the past ages. In

Plate IV., Fig. 3, the substance of which these rings is composed is seen coalescing, and thus forming a ring.

In Plate III., Figs. 2, 4, Plate IV., Figs. 3 and 4 of this paper are shown channels extending from these canals conveying the calcium carbonate to the outer surface of the stem, and similar features are shown to the left and top in Seward's figure (loc. cit.).

If Professor Seward had had a more perfect specimen upon which to work, it would probably have been found that what are thought to be leaf traces would prove to be silica channels corresponding to the calcium carbonate channels in the Sydney specimen and the "crushed parenchyma tissue" referred to as "traumatic" may possibly be tracheids detached by the silica, for they very much resemble in character and disposition those found in the Sydney specimen.

Like the Antarctic fossil, the Sydney one is wanting in bark.

As these two specimens have thus several specific features in common, the Sydney specimen has been systematically placed in the Genus *Antarcticoxylon*, with the species name of *Raei*, after Mr. J. L. C. Rae, to whom the author is so much indebted for the specimen upon which this investigation has been carried out.

As the geological age of the Antarctic specimen is not known definitely, it may eventually be found, in view of so much agreement in structure, as now shown to exist in the two, that they are of the same period. The main difference between the two is the presence of silica and calcium carbonate respectively in each.

It is well known amongst geologists that fossil plants and their parts are often found incrustated, and their parts permeated with calcium carbonate, which acts as a pre-

servative, and sometimes forming a perfect cast of the plant, the presence of this substance being attributed to the influence of water saturated with calcium carbonate.

Whilst this latter may be true in some cases, yet the author is of opinion that in some instances it is present in excess in the soil, in which case it is broken down by the root hairs and passed into the plant structure for the purpose of (1) building up the cell walls, and (2) encasing the tree for self preservation, and these two are illustrated in the Sydney specimen.

Under no circumstances is the author prepared to admit that it is a valueless structure—in fact, nothing is a valueless structure in nature, and further, if the tree didn't need it, the root hairs would not absorb it.

In this case one sees a splendid system of mechanism, all the parts of the tree working as a machine, in order to triumph or overcome adverse conditions of environment.

It is generally thought that the calcification and silicification of fossil wood takes place after the tree has died, but it is difficult in this case to understand how such took place after the tree was dead, for then the root hairs were dead also, and so could not function, that is, dissolve the calcium carbonate and pass it into the tracheids, displacing the cellulose (if such existed) of the walls, and substituting the carbonate of lime, and further, depositing it in the outside of the tree.

Then one is faced with the mystery as to why nature does not let the wood decay or rot, and so be saved all this labour, for as far as we know, this preserving of the timber serves no purpose in nature, and also whence comes the mechanical power which forces the calcium carbonate through and through the whole wood structure, if the root hairs are dead?

As stated above, the calcium carbonate is not evenly distributed on the exterior surface of the tree, being far more heavily deposited on one side than the other, a circumstance which well illustrates Rule I. in Newton's *Principia*:—"Nature does nothing in vain, and *more* is vain when *less* will serve," and so *more* is required in this case to resist adverse climatic conditions, and *less* "*serves*" on the side facing the sun.

Turning from the pointer-readings, and concentrating on what can only be inferred by the mind to explain this arrangement of calcium carbonate by nature, one wonders whether this deposit in the tree indicates a period in arboreal life when trees had no bark—a material later introduced perhaps by nature to protect the new internal structure and tender Cambium, for this latter appears to be absent from fossil trees.

It may be mentioned that amongst living trees, the bark of "Grey Mangrove," *Avicennia officinalis*, as such, is negligible, there being no cambium to protect, but in order to resist the shearing action of the water of tidal rivers, nature builds the stem with a ply structure—the only one of its kind in the whole botanical world. (Vide paper by the author, *Roy. Soc. N.S.W.*, Vol. XLIX, 1915).

In conclusion, one may quote the words of Professor Judd: "We still regard fossils as the medals of creation—representing periods like ancient coins."

#### Acknowledgments.

I wish to acknowledge with thanks the help received from the following gentlemen: Mr. A. R. Penfold, Curator and Economic Chemist, for the loan of books and chemical information; Mr. M. B. Welch, Economic Botanist, for furnishing some botanical data; Mr. F. R. Morrison, Chemical Assistant, Technological Museum, Sydney; Professor F. S.



Cotton, Sydney University; Mr. W. S. Dun, Palaeontologist, Department of Mines, Sydney; Mr. F. Chapman, Commonwealth Palaeontologist, Melbourne; Mr. L. C. Ball, Chief Government Geologist, Brisbane.

Especially am I indebted to Mr. D. Scully, for it was his publicity of the "find" that prevented it passing into the limbo of oblivion. And lastly, but by no means least, to Mr. J. L. C. Rae, Redhill, Newcastle, N.S.W., for it was by his foresight in preserving the only specimen, now extant, of this fossil tree, that this research has been made possible. He very kindly placed it at my disposal for investigation, and so science will be indebted to his generosity for this additional knowledge of Australian geology, and the specific rank will now bear his name.

#### EXPLANATION OF PLATES.

##### Plate III.—

Fig. 1.—A perspective view of the specimen of fossil timber from the Sydney Harbour Colliery. Nat. size.

Fig. 2.—An end view of above. The light coloured portion is calcium carbonate. Slightly enlarged.

##### Plate IV.—

Fig. 3.—Upper portion of Fig. 2. The annual rings are clearly defined, the darker circles marking the autumn growth, the lighter areas the spring growth. To the left, the clusters of circular bodies are calcium carbonate canals and from the pith is seen a horizontal channel extending to the outer surface of the stem. Medullary rays are seen to be very fine and numerous. X2.

Fig. 4.—Structure surrounding the pith more highly magnified. The body below the pith is not a leaf trace but a calcium carbonate canal. X3.

##### Plate V.—

Fig. 5.—Transverse section through portion of the timber. The dark area of tracheids marks the autumn growth of an annual ring, the lighter upper portion, the spring growth. X40.

Fig. 6.—Transverse section through spring growth, showing the variation in the number of rows of tracheids between the rays—white lines filled with calcium carbonate. In a few tracheids, manganese compounds can just be detected. X40.

Fig. 7.—Radial section showing (1) uniseriate rows of bordered pits in centre tracheids, (2) rays with simple pits and absence of Abietinæ markings. X35.

Fig. 8.—A higher magnification of Fig. 7, showing more clearly the bordered pits and simple pits in the ray parenchyma. X40.

Fig. 9.—A radial section showing how the tracheid tangential walls are weakened by the numerous bordered pits (in section). X40.

Fig. 10.—A tangential section showing bordered pits on tangential walls and end-on view of rays mostly filled with calcium carbonate. X50.

Plate VI.—

Fig. 11.—A radial section showing on centre tracheid black spherical bodies of the manganese compound, a unique form, as it usually occurs in a continuous body. X40.

Fig. 12.—Transverse section showing shape and contour of pith and surrounding primary xylem. X35.

Fig. 13.—A transverse section through a vertical canal, showing how calcium carbonate is discharged into it from a few rows of tracheids (see also bottom Fig. 3) much resembling the transfusion tissue of Angiosperms. The black band surrounding the calcium carbonate is composed of displaced tracheids. X40.

Fig. 14.—Radial section through a vertical canal of calcium carbonate, showing xylem structure on each side of it. X40.

Fig. 15.—On the right, a mass of calcium carbonate with displaced tracheids scattered throughout this substance. X40.

Fig. 16.—A higher magnification of the outer edge of the calcium carbonate shown in Fig. 15.

## NOTES ON BATHYLITHS AND SOME OF THEIR IMPLICATIONS.

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*(Read before the Royal Society of New South Wales, Aug. 5, 1931.)*

### Introduction.

The term *bathylith* was originally employed by Suess<sup>1</sup> to signify large masses of plutonic igneous rock, which, he believed, were cake-like in form, and filled pre-formed open spaces in the earth's crust. Later he assumed for them a shape and a mode of origin which postulated their extension downwards to unknown depths.

Since Suess' time very varied conceptions of the origin, mode of emplacement and shape of these masses have been expressed by different geologists. Daly<sup>2</sup> has devoted considerable attention to these matters, and has endeavoured to give more precise significance to the term by summarizing the general characteristics of bathyliths and by assembling and describing maps and sections of a number of such intrusions. A consideration of the examples cited by Daly and others makes it clear that there have been grouped under one general heading intrusive masses differing from each other in many respects, and evidently brought into position under very different circumstances; and from time to time indications have been forthcoming that investigators have been in doubt as to the propriety of describing certain intrusions as bathyliths.

Adams and Barlow<sup>3</sup>, following Lawson, used the term in connection with their Haliburton-Bancroft work "to designate great lenticular-shaped or rounded bosses of granite or gneiss, which are found arching up the overlying strata through which they penetrate, disintegrating the latter, and which possess a more or less distinct foliation, which is seen to conform in general to the strike of the invaded rocks when these latter have not been removed by denudation."

Some authorities are opposed to the description of rock-masses like these, which exhibit concordant instead of cross-cutting relations towards the invaded formations, as bathyliths; nevertheless there seems on the whole a general tendency among geologists to describe under this head all large plutonic intrusions, whether transgressive or not, which are of such dimensions, and whose field-relations are such, as to prohibit their classification as sills, laccoliths, dykes or similar types. Since there is no agreement, and little prospect of agreement, about the shape and underground relations of bathyliths, and since indeed these may vary in different cases, it is best in the present state of our ignorance to exclude any particular connotation as to shape, relations to invaded rocks, or mode of emplacement from the use of the term.

In a posthumous paper by Barrell<sup>4</sup> a useful distinction is drawn between orogenic and plateau bathyliths, the former comprising those which are associated with regionally-metamorphosed sediments and have been injected under conditions of tangential or horizontal compression, the latter those that have been injected at a time when vertical crust-movements were dominant.

In a later paper by Billings<sup>5</sup> these types are referred to as synchronous and subsequent bathyliths respectively,

these descriptions having reference to the contemporaneity or otherwise of intrusion with orogenic epochs.

According to Balk<sup>6</sup>, German geologists distinguish between gneissoid granites, which appear as elongated masses parallel to the regional trend, and granites proper, which exhibit cross-cutting relations. These differences in behaviour are regarded as significant; they have been interpreted by Professor Cloos in a paper which, unfortunately, is not available to the present writer. Balk, apparently, does not consider the masses of gneissoid granite as true bathyliths.

The recognition of two main bathylithic types according to the tectonic conditions prevailing at the time of injection is extremely important and very necessary, since, while all bathyliths appear to be associated in time with mountain-building epochs, as Daly has observed, there is plenty of evidence that the actual conditions attending the injection of the magma may differ very materially, and the differences are reflected in the external relations and internal characters of the intrusive masses.

The necessity for distinguishing two main types of abyssal intrusion having become apparent, some revision of Daly's summary of characteristics is called for.

From a study of some of the pertinent literature, and from the examination of a number of both synchronous and subsequent intrusions in this State and elsewhere in Australia, the author is moved to put forward some generalizations with regard to them.

#### **Characters of Synchronous Bathyliths.**

Synchronous bathyliths generally show all or most of the undermentioned characteristics:—

- (a) There is constant association with schists or other regionally-altered and highly-folded rocks.

- (b) Boundaries are steep or vertical in section, in plan parallel or sub-parallel with the strike of the enclosing rocks but often ill-defined through gradation from the invading into the invaded rock; outcrops are markedly elongated parallel to the axis of folding, and peripheral lenses may be numerous.
- (c) The roof is highly irregular, tending to fray out into sills and parallel lenses and tongues.
- (d) Gneissic structure is commonly developed in the igneous rock, either primary alone or primary and secondary, the banding or foliation being parallel to the boundary of the intrusion and sometimes varied with minor crinkles and contortions.
- (e) Abundant pegmatite is generally present, both as peripheral *lit-par-lit* injections and within the mass as contemporaneous stringers and as definite dykes.
- (f) Inclusions are common, elongated parallel to the walls and the gneissic banding, and not deorientated.
- (g) No hornfelsing of the country-rock has occurred, though this may have suffered much alteration through impregnation (granitization).
- (h) There is little or no indication of serial differentiation in the intrusion, but pegmatite and gabbro dykes may appear, possibly as complementary differentiates; dynamic differentiation through squeezing out of residual magma may also be apparent.
- (i) Minerals like andalusite, sillimanite, cordierite, garnet and epidote may be present in the granitic igneous rocks, either through contamination or as primary crystallizations. Some local modification of the granite through incorporation of country-rock may occur.

**Characters of Subsequent Bathyliths.**

The following are the chief contrasting characters of subsequent bathyliths:—

- (a) No necessary association with regionally-metamorphosed rocks is observed; the country rock may be only moderately folded.
- (b) Boundaries are mostly sharp, and cross-cutting relations general, though there may be local concordance with the enclosing strata; outcrops are irregular in plan. Peripheral lenses are absent, but there may be dyke- and sill-apophyses.
- (c) Indications may point to the roof having been fairly flat, or irregularly domed.
- (d) The granite is in general massive, though marginally it may have directive structures.
- (e) *Lit-par-lit* injection is scarce or absent, and there is a general scarcity of pegmatites, except as segregation-veins, but fine-grained aplites are common, sometimes accompanied by lamprophyre dykes.
- (f) Inclusions are angular and deorientated.
- (g) Where the country-rocks have not suffered much previous metamorphism a contact-aureole is present, with typical contact-minerals, not usually, however, of very high-temperature formation.
- (h) Extensive serial differentiation is indicated, often with evidence of more than one injection of magma.
- (i) Contamination through incorporation of country-rock is not in general noteworthy.

**Notes on Synchronous Bathyliths in N.S.W.**

The data concerning the synchronous bathyliths in this State have been obtained mainly from a study of occurrences in the Barrier Ranges, and on the Monaro plateau

around and to the north of Cooma, as well as from a brief examination of the granite at Albury.

The first have been the subject of detailed mapping and investigation by the Government Geologist, Mr. E. C. Andrews, and his assistants<sup>7</sup>, and a study of the maps accompanying the Memoir on the area reveals very strikingly the field-characters of the igneous intrusions. The Willyama (Archaeozoic) Series, dominantly of pelitic sediments, was highly metamorphosed and folded, and injected by granitic gneisses, with accompanying gabbros and pegmatites, probably at the close of the Willyama period of sedimentation. The granites and some of the gabbros have a marked primary gneissic structure, often with a cataclastic foliation superimposed. The sill-habit is by far the most common for both acid and basic rocks about Broken Hill, but outcrops suggesting phacoidal forms are also common, especially for the granite-gneisses, around which in places the sedimentary schists are seen to be bent. Transgressive boundaries are practically if not entirely unknown, and indeed the structures of domes and basins in the sedimentary series are indicated by the intercalated sills of granite and gabbro.

In his sections across the area Mr. Andrews makes it clear that he conceives all these linear outcrops to be parts of a few far-flung narrow parallel intrusive sheets or layers of igneous material which have taken part in the folding of the whole terrain and then been revealed by erosion; the same view is stated more or less explicitly in the text of the Memoir.

The impression gained by the author from a personal examination of much of the area, partly under the guidance of Mr. Andrews, is that the igneous intrusions as we see them to-day are substantially in the same attitudes and



orientations as when they were first consolidated, and that the magma was forced or insinuated up along pre-existing planes of weakness, during the folding of the sedimentary rocks, but after their regional metamorphism had been accomplished.

This is shown by the primary gneissic foliation of the granites, by the intimate interleaving of sillimanite-schist with granite-gneiss and by the presence in the gneiss of inclusions of schist and of metamorphic minerals derived therefrom. In the sills the foliation is generally vertical, though it may dip at low angles where there has been local buckling of the strata; in the phacoidal outcrops the planes of foliation may dip inwards or outwards at steep angles.

It is rather unfortunate that there is no dissection of the Barrier Ranges of sufficient magnitude to afford some clue as to the relations in depth between invading and invaded formations, but it appears most reasonable to suppose that the various sills and lenses connect downwards more or less directly to one or more large masses of granitic magma underlying the whole central part of the Broken Hill area, from which they were originally forced up concordantly along the bedding-planes of the altered sedimentary rocks. Indeed some of the larger roughly lenticular outcrops of porphyritic and non-porphyritic primary granite-gneiss might themselves be regarded as small synchronous bathyliths, or as protuberances from the upper portions of such bathyliths.

At Cooma, Ordovician schists with a meridional strike are invaded by two related granitic intrusions, both probably of late-Ordovician age<sup>8, 9</sup>. The earlier of the two appears almost entirely in the form of innumerable narrow concordant sheets or sills. The second intrusion, which is the more important and extensive, is in places massive, but

elsewhere has marked primary banding. It makes a continuous outcrop in and about the town, and to the east its boundaries are more or less sharp, but to the west away from the main mass there are abundant narrow sills and lenses of gneiss or granite. The solid outcrop also frays out into tongues and sills to the north, and these apparently join into two separate parallel sill-like masses which may be traced to a point about 15 miles north of Cooma, where they are cut off by a later intrusion in which fragments of gneiss may be recognised for a further eleven miles at least. It is inferred that the solid outcrop at Cooma is a portion of the main bathylithic mass, that the outlying lenses and sills are upward penetrations from the roof, and that the northward extensions, if they could be followed downwards, would be found to unite into one mass continuous with that exposed at Cooma.

*Lit-par-lit* injection of the schists by pegmatitic material is very marked at Cooma, and in addition the schists have been thoroughly soaked by magmatic fluids and granitized. At Broken Hill, *lit-par-lit* injection of the schist is not so much in evidence, possibly because of the abundant mantle of alluvium and blown sand round the igneous masses, but there is in places an abundance of pegmatitic stringers through the gneiss itself, and at the margins there may be such interleaving with the country-rock and such an apparent gradual passage from sedimentary schist to igneous gneiss that an actual boundary between them is very difficult to draw.

At Broken Hill, Cooma and Albury the presence of aluminous minerals in the granites is quite a striking feature. In the first locality little lenticular aggregates of sillimanite about a couple of inches in length, sometimes longer, often surrounded by a rim of sericite, are quite

common as marginal enclosures in certain of the more acid igneous rocks, while cordierite is a constituent of some pegmatites and aplites. The sillimanite lenses seem to be essentially similar to those described by W. J. Miller<sup>10</sup> as occurring included in a granite in New York State. Garnet in various stages of disruption is also found in certain phases of nearly all the granitic rocks. Of the Cooma gneiss cordierite and sillimanite are quite common and notable constituents, while sillimanite alone has been found in the Albury granite. Undoubtedly the presence of some of these minerals is due to incorporation of country-rock by the magma, though in other cases they appear to be primary crystallizations.

Another common feature of the synchronous bathyliths is the presence of marginal inclusions of country-rock which are very much elongated and have not suffered deorientation. These are not so evident at Cooma as about Broken Hill, where, along the margins and even near the centres of the granite-gneiss outcrops, there have been found these elongated inclusions of country-rock, some recognisably of sedimentary origin, but others of altered basic igneous rocks, which may easily be mistaken in the field for concordant sill-like intrusions through the gneiss. An instructive section through the granite-gneiss is to be found in a cutting on the Menindie railway-line at Broken Hill, a small portion of which is illustrated in Plate LVIII. of Mr. Andrew's Memoir. The basic rocks, here, gabbros and amphibolites, are in part no doubt intrusive through the granite-gneiss, but some would appear to be basic schists which antedate the gneiss, and which were intimately penetrated by the granite-gneiss magma during its intrusion.

In some instances it may be that the masses of country-rock which appear as inclusions owe their present orientation to their having been softened and pulled out in the

flowing magma, but in other cases it seems evident that the magma made its way by a process of "peaceful penetration," thin veinlets insinuating themselves outwards and upwards along planes of weakness in the schists, and gradually isolating very elongated masses which, though moved laterally, were moved so very uniformly that they never lost their orientation. Others again of these apparent inclusions which retain their original orientation may be really remnants of an irregular roof, like the "roof-pendants" described by Daly.

Examples of abundant orientated—or undeorientated—inclusions in granite-gneiss have been described and figured by Lacroix<sup>11</sup>, Peach *et al.*<sup>12</sup>, Lawson<sup>13</sup>, Adams and Barlow<sup>3</sup>, Fenner<sup>14</sup>, Billings<sup>5</sup>, Tilley<sup>15</sup>, and a host of other workers. So abundant in some bathyliths are these inclusions in all stages of disintegration and incorporation that Foye<sup>16</sup> in 1916 was moved to suggest the term *stromatolith* (layer-intrusion) instead of bathylith to describe those large concordant plutonic masses in which orientated inclusions form a conspicuous feature. The name does not appear to have come into general use, possibly because it tends to over-emphasize the part played by the layers of sedimentary rock in the intrusive mass. Nevertheless, the intimate sandwiching of innumerable veins or narrow sills of igneous material is undoubtedly an important feature of some synchronous bathyliths, where, indeed one may trace all gradations from igneous rock with linear inclusions of country-rock outwards into country-rock intimately seamed with igneous veins. The present writer, however, is inclined to regard these phenomena as being essentially marginal, either along the sides of the bathylith or at the top part where it frays out into an irregular roof, and not as being characteristic of the whole mass of the intrusion.

It is only in connexion with synchronous bathyliths that the author has observed true dykes of pegmatite, and especially the association of dykes of pegmatite and gabbro. Among the massive granite dykes of aplite, with or without complementary rocks, occur, but pegmatites appear mostly as segregation-veins. The conjunction of coarse acid and basic rocks cutting through the granite-gneiss, as at Broken Hill and Cooma, suggests a complementary relation.

Acid gneisses are found, though not extensively, along the margins of the granite-gneiss intrusions at both Broken Hill and Cooma, produced, it would appear, by dynamic differentiation like that described by Barrow for the granites of the South-Eastern Highlands<sup>17</sup>.

An intrusion which is of the synchronous type, but which lacks some of the characters listed above, is the Upper Murrumbidgee bathylith, extending from Cooma northwards for about sixty miles into the Federal Capital Territory. Though it has not as yet been completely investigated, sufficient is known of its occurrence to permit of its main characters being determined, and a short description of it has been given elsewhere<sup>9</sup>. It differs from the intrusions already described in its association with slate as well as schist, in the complete absence of *lit-par-lit* injection and in the surprisingly small amount of contact-metamorphism associated with it. Also, though peripheral lenses of the intrusion are locally numerous and the intrusion frays out into a number of tapering tongues to the south, there is no shading-off or merging of intrusion into country-rock, and the boundary between invading and invaded rock is generally sharp. The main rock type is a quartz-mica-diorite grading into granite, but there is in places marked marginal development of very acid aplitic gneiss. Aluminous minerals produced by assimilation of

sediments are lacking, but well-crystallized primary epidote appears to be a constant constituent, in the marginal quartz-diorite at all events. It would appear that the conditions of heat and dynamic pressure attending this intrusion were less intense than in the other cases considered, and evidently the magma was less rich in volatile constituents.

A consideration of some of the characters of these intrusions enforces the conclusion that they were all injected after regional metamorphism had altered the sedimentary rocks, but while conditions of strong dynamic pressure still prevailed.

#### Notes on Subsequent Bathyliths.

The great majority of the known bathylithic intrusions in this State belong to the subsequent type, and the writer has tried elsewhere<sup>9</sup> to show that in the main these belong to two main epochs of intrusion, the one at the close of the Devonian Period and the other near the close of the Permian. But little has been done toward a systematic investigation of these intrusions, and it is doubtful whether the complete boundaries of any one bathylith have ever been traced. However, the general characteristics attributed to this type of intrusion, as listed above, have been determined as a result of the partial examination of a number of examples in this and other States.

Although it is true that massive granites are often found outcropping amid regionally-altered rocks, there are usually indications that these have received the metamorphic impress long before the date of the intrusion, and have really formed the floor for the geosynclinal sediments, now eroded away, which were folded just before the intrusion occurred. But it is probably the usual case that the granite has originally penetrated through the floor and

in among the just-folded sediments, and where these are found outcropping about the bathylith they may show little or no regional metamorphism, though contact-alteration may be marked.

It is apparently not uncommon to find in the subsequent bathyliths, in addition to the predominant granite or quartz-monzonite, minor amounts of more basic rocks such as granodiorite, diorite, gabbro, pyroxenite and hornblendite, and even peridotite, with intermediate connecting varieties. The consanguinity of these with the granite is clear on mineralogical and chemical grounds, and their field-relations may be such as to suggest a series of intrusions from some more deep-seated reservoir of differentiating magma. Examples are furnished by the Moruya<sup>18</sup> and Hartley<sup>19</sup> intrusions in this State and by the Meredith Range and other composite bathyliths in Tasmania.<sup>20</sup> In certain instances somewhat alkaline rocks may appear as final differentiates.<sup>21, 22</sup>

The very fact that this serial differentiation, whatever its mechanism, has been possible, points to the prolonged existence of tranquil conditions during the cooling of the magma. Moreover, the general absence of signs of regional metamorphism in the surrounding sediments, and of directive structures in the igneous rocks themselves, together with the cross-cutting relations of the intrusion, would indicate in the first place that conditions of compression had never been at any time very strongly marked, and, secondly, that compression had ceased and been replaced by tensional conditions at the time of injection of the igneous magma.

#### **Depth-Variations in Habit and Structures of Bathyliths.**

It may be argued that, just as the unaltered sedimentary rock may grade downwards into phyllite and schist as a

result of deep burial, so the massive transgressive granite of the subsequent bathylith may pass at depth into gneissic granite and granite-gneiss with the concordant habit of the synchronous intrusions—in other words that the differences in habit and appearance of the two types of intrusion as seen in outcrop are simply functions of depth of erosion. Barrell (*op. cit.* pp. 5 and 6) considered that different types of bathyliths owe their distinctive characteristics to the fact that “they may have approached to within a few thousand feet of the surface of the earth, into a zone of fracture and rapid cooling, or they may have ceased their upward progress at a depth of miles, while still in the zone of flow . . .”

Blackwelder and Baddley<sup>23</sup> apparently had something similar in mind when they wrote that “cross-cutting relation is characteristic of the more superficial parts of a bathylith and especially of those that approach nearer the surface, while at very great depth the marginal rocks become plastic and flow, making contorted gneisses.”

In both these quotations there appears to be the implication that pressure and temperature are functions of depth, and depth below the surface is emphasized as the controlling factor in producing the distinctive features of synchronous and subsequent bathyliths. While this may be regarded as in a general way correct, there are certain phenomena which tend to show that the habit and internal structure of the bathyliths depend not on the existence of some actual limiting depth, but rather upon the conditions of temperature, and particularly pressure, existing at the time of injection and at the level of injection, conditions which may change from time to time. The most striking illustrations of this fact within the author's knowledge are to be seen in the neighbourhood of Broken Hill, where the masses of granite-gneiss with concordant habit are inter-



sected by small boss-like outcrops of perfectly massive fine-grained granite, exactly similar to the surrounding gneiss except for the total absence of directive structures, and beyond reasonable doubt derived from the same magma and injected during the same epoch of intrusion. It is a fair assumption that the load or depth of cover had not changed materially in the interval between the two sets of intrusions, and the conclusion is enforced that the differences in habit and internal structure are the result of change in the pressure-conditions, the horizontal or folding forces having died out and been replaced by tensional forces.

The change from compressional to tensional conditions after the consolidation of the main body of magma is also indicated by the existence of dykes of unstressed pegmatite, comagmatic with the granite, cutting across the primary gneissic foliation.

In this connexion a statement of Dr. Harker's has special significance. Commenting on Grubenmann's assumption that regional metamorphism is related simply to depth below the surface he remarks:<sup>24</sup> "We can conceive ideally a globe in which the temperature, like the pressure, increases steadily downwards; but it is of the essence of metamorphism that it is related to a very notable disturbance of this ordered state of things in some part of the earth's crust." In like manner the special characteristics of the synchronous bathylith, which is so closely associated with regional metamorphism, are not to be related simply to the normal change in temperature and pressure conditions with depth, but rather to the same special and transient conditions which have effected the metamorphism.

Nevertheless the habit of a plutonic intrusion, or its attitude towards the enclosing rocks, though not necessarily its internal structures, may be in some degree dependent on

depth, and may be found to undergo a change when traced downwards. In considering the results of horizontal compression of a portion of the earth's crust which has been the site of a geosyncline it is necessary to distinguish two elements which in general behave differently towards the compressive forces. The first of these elements consists of the recently-deposited sediments, now for the first time subjected to horizontal compression; these become folded and, perhaps, cleaved and metamorphosed, and overthrust along planes of low inclination. The second element is composed of the rocks which form the floor or basement of the geosyncline; these have probably been compressed and, it may be, strongly folded and metamorphosed during a much earlier period, so that from their attitude and condition they are now no longer capable of further folding, but act as more or less rigid masses which can yield only or mainly by thrusting along shear-planes. If the basement rocks are old igneous intrusions the same will happen. Lawson<sup>25</sup> and Daly<sup>26, 27</sup> are of the opinion that underthrusting is the most likely method of yielding, and the former considers that the gliding surface should be concave downwards, gently dipping above, but steepening rapidly below. It seems at least arguable that overthrusting would be just as likely to occur, in which case the curve of the gliding surface would be reversed, with the concavity upwards, a steep dip above shallowing rapidly almost to horizontality below; this would harmonize with Keith's<sup>28</sup> conception of the attitude of these rock-partings. However, the important point is that there would be differential thrusting movements of blocks or masses of the basement. The planes or zones of shearing, being very deep-seated, would naturally be very different from the flat overthrusts affecting the overlying folded sediments, and the intensity of the shearing would vary according to circumstances. The strikes of

the principal shear-zones would be more or less normal to the direction of horizontal pressure, and hence parallel to the axes of the folds produced in the overlying sediments. though not necessarily parallel to the strike of the basement-rocks, while there might be other minor transverse shear-zones. Reference to the shear-zones of the Barrier Ranges, which the author believes to have originated in this way, is made below.

Now when, either during or after folding, magma was forced upwards, its passage would be facilitated by the existence of the zones of weakness produced by the shearing and dislocation of the basement-rocks; its introduction at intervals along such shear-zones would therefore directly determine the general parallelism that so often exists between the arrangement of the bathyliths and the strike of the sediments among which they were injected. On the removal of these sediments by erosion, however, the bathylith would be seen to have no parallelism with the strike of the surrounding basement-rocks, except, of course, in the case where this happened to coincide with the axes of folding of the overlying sediments. Thus the orientation of an intrusion toward the country-rocks might be different in its upper and in its deeper parts.

What would appear to be an illustration of the foregoing principle is to be seen in the composite bathylith at Moruya, on the South Coast of New South Wales. According to Miss Ida A. Brown,<sup>18</sup> who has examined and mapped the area, the bathylith makes an elongated outcrop about three to four miles in width, which has been traced for twenty miles in a N.N.W. direction and extends much farther, the boundaries of the mass being sub-parallel. The invaded rocks, of early Palaeozoic age, are closely folded along a meridional direction, so that the bathylith cuts obliquely across the strike of the fold of these rocks. There are, as

Miss Brown shows, reasons for believing that the intrusion is of late-Devonian age, and, as a matter of fact, about six miles west of Moruya and not far from the granite boundary, gently-folded Devonian sedimentary rocks outcrop with a N.N.W. strike. The elongation of the bathylith, or of that part now remaining, is therefore parallel to the Devonian axis of folding, and it is the erosion of the roof rocks that has revealed the basement of older close-folded strata on which they were deposited. It is not unreasonable to suppose that the position and trend of the intrusion have been determined by a zone, or a series of zones, of dislocation developed through these basement rocks parallel to and contemporaneously with the folds in the overlying Upper Devonian strata.

#### Shape of Bathyliths.

It would appear from a consideration of the circumstances attending their injection, that the relations of synchronous and subsequent bathyliths towards the just-folded sediments will differ considerably, with a consequent difference in the shape of the upper parts of the intrusions. Where the folding of these geosynclinal sediments has been so intense as to produce sub-vertical cleavage and schistosity the synchronously-injected magma would tend to be forced up along these planes of relatively easy progress, and perhaps, by assimilation and replacement, might make way for itself so as to form sheet-like or phacoidal masses which would be relatively narrow, since there would be a direction of minimum ease of progress at right angles to the planes of weakness. But where the sediments had not been severely folded and regionally altered there might be a strong tendency for the magma, especially if severe horizontal compression had ceased, to spread out more or less laterally when it had reached the level of the base of the geosynclinal sediments, since the inducements to vertical

progress would then not be so great. This lateral progress might be primarily directed by the surface of unconformity, or by flat planes of overthrust developed in connexion with the folding of the sediments, but much vertical progress might be made along planes of jointing and dislocation, and by means of overhead stoping. Thus the subsequent bathyliths might really be of the nature of great floored intrusions, as imagined by Brøgger<sup>29</sup>, Harker<sup>30</sup> and Iddings<sup>31</sup>, and as inferred by Cloos from field-observations, whereas the synchronous bathyliths, elongated and concordant, might be of the shape that Daly conceives all bathyliths to have, with sides sloping steeply downwards, and extending without interruption or constriction to abyssal depths.

#### **Bathyliths and Mountain-Building.**

The association of bathyliths with regions and epochs of mountain-folding has often been stressed, and Daly has laid it down that "bathyliths are situated in a folded belt, and their date of intrusion has followed more or less closely an antecedent period of mountain-building." It would appear that in no case has a bathylith been found intrusive through flat-lying, unfolded sediments, and it is fairly safe to assume that there is a close relation between plutonic intrusion and crustal movements. But the differences between synchronous and subsequent bathyliths are very great, and it is necessary to explain these differences in terms of environment, or conditions prevailing during injection, while at the same time relating both types of intrusions to mountain-building movements.

It seems to be agreed at the present time by many students of mountain-building<sup>32</sup> that the formation of the great mountain-ranges of the world is not in general due to folding alone, but is the resultant of two main movements. First, there has been tangential compression and folding of geosynclinal sediments, which may or may not in

itself have resulted in considerable elevation of the sediments above sea-level. An interval of erosion seems to have succeeded, followed eventually by a movement of general vertical uplift; and it is this last which has accomplished most of the actual elevation of the mountain-range. The term *orogenic* has therefore lost its strictly etymological significance of *mountain-building* and must be employed simply to indicate folding. Though the folding and vertical movements may have been separated by a very long interval indeed measured in years, they are to be regarded as phases of the one mountain-building movement, and apparently in the past it has happened that the compressional and tensional movements and subsequent extensive denudation of the elevated region have all been completed in the interval between one geological period and the next, this interval being a diastrophic epoch.

It would appear not improbable that the distinctions between synchronous and subsequent bathyliths which may be attributed to environment are due to the fact that the former were injected during the first or compressive phase of the mountain-building movement and the latter during the second or tensional phase. If this view is correct the terms *synchronous* and *subsequent* should have reference to the contemporaneity or otherwise of the act of intrusion with the compressional phase, and not with the mountain-building movement as a whole.

Keith<sup>28</sup> has argued that mountain-folding results from synchronous igneous intrusion, and Barrell<sup>3</sup> that regional metamorphism is largely due to the same cause, but in the author's experience, certainly limited, there is clear evidence that considerable folding and regional metamorphism have been accomplished prior to the emplacement of the synchronous bathylith, and this agrees with the observations of others.<sup>5</sup>

In any case, on *a priori* grounds, the wonderful coincidence of the axes of synchronous intrusion with the strike of the folded beds is surely most reasonably to be explained as due to the folding forces having operated first, the magma being injected along the direction and in the positions thereby determined, and, besides, the orientation of inclusions, the gneissic banding, and above all the development of acid fringes on the leeward margins of synchronous bathyliths, indicate that the magma was the passive plaything of the orogenic forces rather than an active agent in producing them. But quite apart from all these considerations, cases have been recorded of moderate to intense folding and strong regional metamorphism unaccompanied by any deep-seated igneous intrusion whatever.

It would appear then that there are serious difficulties in the way of considering synchronous bathyliths as important factors in producing folding and the regional metamorphism which often accompanies it.

The case, however, is somewhat different when subsequent bathyliths are considered. If, as suggested above, there is some lateral spread of the magma at the upper levels along shear-planes or other surfaces of discontinuity, then the liquid magma under great pressure from below, and acting as a great hydraulic ram, may actually cause the broad gentle doming-up of the superincumbent strata on a regional scale, and so be an important, if secondary, factor in the second or uplift phase of the mountain-building movement.

It is not clear why plutonic injections should sometimes accompany folding and sometimes succeed it, nor why the intensely folded and altered sediments should have synchronous intrusions associated with them, while the moderately or gently folded and little altered sediments should be invaded only by subsequent intrusions.

An explanation may, however, be attempted on the basis of the theory of mountain-building advanced by Joly.<sup>32</sup> It seems legitimate to assume that the thicker the accumulation of sediments in the geosyncline the greater will be the intensity of folding and metamorphism suffered by the lower portions of them on the collapse of the geosyncline, both by reason of the depth of the zone of weakness in the earth's crust and because of the increased heat and pressure due to deep burial and the weight of superincumbent strata. The outcrops of highly folded and altered strata may therefore be looked upon as merely the remnants left by erosion of an originally very thick sedimentary series. Apparently thicknesses of as much as eight or ten miles of sediment have accumulated in some geosynclines before their final collapse.

Joly considers that the transgression of the ocean waters over the land follows on a sinking of the continental granitic layer of the earth in the basaltic substratum when this latter has been liquefied as a result of the storing-up of radioactive heat. The formation of a geosynclinal trough on the continental layer presumably necessitates local depression of the lower parts of this layer into the hot basaltic substratum, and the subsequent collapse of the trough and folding of the sediments involve by way of isostatic compensation a further depression of the granitic layer, with probable liquefaction. According to Joly "in the great vertical pressures from beneath, which act on such a protuberant mass, the mechanism which brings about intrusion of plutonic continental magmas into the heart of the mountain range finds direct and simple explanation." These vertical thrusts are induced especially during the regelation of the basaltic substratum, when also vertical elevation of the folded sediments is produced.



Now if the geosyncline be very deep the layer of granitic material underlying its floor may be thinned and weakened to such an extent that when folding of the sediments takes place the fused lower portions of the continental layer may be forced upwards through the shattered basement-rocks and among the folded sediments. Later when regelation of the basaltic layer causes the vertical phase of the mountain-building movement to occur, and the upper folded sediments are in a state of tension, the vertical pressure may force further magma upwards through them to form subsequent intrusions.

Where, however, there has been but little sagging of the crust, and a relatively shallow syncline has been formed, only moderate folding and little metamorphism will result from lateral pressure. The solid granitic layer will not be seriously thinned either through depression of the geosyncline or through isostatic compensation on its collapse, and so there will be no intrusions synchronising with the folding, only the granitic magma forced up by vertical pressure on regelation of the basaltic substratum appearing among the folded and elevated sediments.

#### **Some Implications of Bathyliths.**

The petrological study of bathyliths has received considerable attention, and there has been much speculation in regard to their mode of emplacement and their relations with the invaded rocks at depth, but it would appear that the historical or stratigraphical aspects of their occurrence have been, relatively speaking, neglected. Doubtless this is due in part to the difficulties, so frequently encountered, of placing the intrusions chronologically, no less than to the fact that the record of the history of the earth's crust is contained overwhelmingly, and is most clearly to be read, in the sedimentary rocks.

The importance of the igneous intrusions of pre-Cambrian times has been recognised in North America, because such a very large proportion of the pre-Cambrian terrain consists of plutonic intrusives that they cannot be ignored. The same state of affairs prevails in Western Australia, where the exposed formations are dominantly pre-Cambrian, the bulk of these consisting of granitic rocks, with minor amounts of altered sediments and lava-flows. Though the Palaeozoic and later granites in Australia do not bulk by any means so largely, still they are of very considerable total areal extent, and are deserving of stratigraphical study. An attempt to place the larger igneous intrusives of New South Wales in chronological order was made by the author<sup>9</sup> in 1929, and Professor E. W. Skeats<sup>33</sup> has recently outlined a suggested chronology for the Palaeozoic granites of Eastern Australia.

But apart from the petrological interests of our bathyliths and the intrinsic importance of the intrusive episodes of the geological story, the larger igneous intrusions may actually serve to throw light on geological events which are otherwise obscure, or whose direct record may have been utterly blotted out. Thus bathyliths may be of value not merely for what they are, but also for what they signify.

The association of bathyliths, whether synchronous or subsequent, with folded sediments is so widespread, and the probability of a genetic significance in this association is so great, that it is not too much to say, from what is known of their occurrence, that bathylithic injection takes place only during some stage of the diastrophism that closes a cycle of sedimentation, and that the magma is introduced under and through the just-folded sediments.

A logical corollary to this proposition would be that wherever a bathylith outcrops we may infer the former

presence, on or over that spot, of a series of geosynclinal sediments, terrestrial or marine, during whose folding and elevation the intrusion of the bathylith took place.

The consequences of granting this inference are important from more than one point of view.

Although it must inevitably happen that the geological age of many bathyliths cannot be determined with any degree of accuracy, still there are many instances in which a fairly exact age-determination may be made, for example through the finding of other outcrops of the same mass, whose relations to the associated sediments are such as to afford age-indications, or through the existence of mineralogical, chemical or structural peculiarities in the rock itself, which point to correlation with other intrusions of known geological age. Now if it is possible by any means to establish the geological age of an outcropping bathylith, then, even though the formation in connexion with whose folding and elevation it was injected has entirely disappeared through erosion, we may legitimately and confidently infer its former existence on the site of the bathylith. Thus the bathylith may have a certain stratigraphical and tectonic value, inasmuch as it supplies some information regarding former episodes of deposition and diastrophism, of which other and more direct evidence has been obliterated.

The stratigraphical implications of plutonic intrusions lead on to an obvious palaeogeographical one.

The palaeogeographer is concerned with determining and plotting the distribution of land and sea, of mountains and lowlands, of areas of erosion and areas of deposition, during different geological periods, and this he does very largely with the aid of geological maps showing the structures and present-day boundaries of the sedimentary formations.

Where, however, the deposits belonging to any one geological period have been removed by erosion over large areas, there may be difficulty in plotting accurately their original extent, and here the outcrops of bathyliths of known geological age may be of material service, inasmuch as they help to indicate sites of geosynclinal sedimentation, and of the resultant or subsequent folding, elevation and erosion.

#### Significance of Some Australian Intrusions.

Some of the foregoing statements will perhaps be better appreciated if a few actual examples be considered.

(a) *The Mundi Mundi Granites of the Barrier Ranges, N.S.W.*

In the Barrier Ranges around Broken Hill, shear-zones, some upwards of 200 yards in width, are developed in great perfection and in considerable abundance through the Willyama (Archaozoic) Series; their distribution can be well studied on the maps accompanying Mr. Andrews' report. In places they cut across granite-gneisses, which are locally converted into cataclastic gneisses and into mica-schists; elsewhere garnet-sillimanite-gneisses involved in the shearing have suffered retrogressive metamorphism into mica- and sericite-schists, while gabbros pass into amphibole-schists. Both longitudinal and transverse shear-zones occur, the former being in some cases traceable into the latter, and the planes of schistosity are vertical or nearly so, while displacement of the affected formations is often marked where the shear-zone crosses the strike of the country. These shear-zones differ from ordinary overthrust planes in the width of the zone affected, in their approach to verticality and in the intensity of the shearing.

Since the metamorphosed Willyama strata and the granite-gneisses injected through them have been alike af-

fecting it is evident that the shearing occurred after the epoch of folding and injection that closed the Willyama period of sedimentation.

To the south-west, west and north of Broken Hill, as at the Umberumberka Reservoir and at Poolamacca, the Willyama Series is invaded by massive as distinct from gneissic granites; these are the Mundi Mundi granites of Andrews. Mawson<sup>34</sup> has described similar granites from Boolcoomatta, across the border in South Australia, which he regards as the equivalents of these Mundi Mundi granites. These granites are clearly much younger than the granite-gneiss; and according to Andrews their positions of injection have been determined by the shear-zones noted above. Directly overlying the granites, and containing boulders of them, are the late-Proterozoic tillites of Poolamacca and Boolcoomatta.

In the Broken Hill Memoir it is argued that the shearing and folding of the Willyama Series are related, and that the Mundi Mundi granites are comagmatic with the Broken Hill granite-gneisses, having been injected during a later stage of the eruptive epoch that closed the Willyama sedimentation.

It is true that instances are known in which intrusions during the earlier part of a mountain-building epoch have been followed by others during the later part of the same epoch, when compressional forces have ceased to operate. But in the particular instance under consideration these later cognate intrusions are to be found, as pointed out above, in the shape of a number of boss-like outcrops of massive granite within the granite-gneiss, and some other interpretation must be sought for the Mundi Mundi and Poolamacca granites; that favoured by the writer is somewhat as follows:

At the close of the Willyama sedimentation metamorphism and folding took place, with the intrusion of the granite-gneisses and gabbros, and subsequently of the little bosses of massive granite during vertical uplift. A prolonged period of erosion was followed by subsidence and further sedimentation in Early Proterozoic times. This in its turn was ended by diastrophism, with folding of the sediments, shearing of the basement schists and gneisses, and injection of the Mundi Mundi and Booleoomatta granites, largely along shear-zones, the main axis of intrusion being perhaps somewhat to the west of its position in closing Willyama times. The erosion that followed completely removed the Early Proterozoic sediments and cut well down into the basement rocks, revealing the shear-zones and laying bare the Early Proterozoic granite. In Late Proterozoic times occurred the deposition of the Poolamacca tillites and other rocks of the Torrowangee Series on top of the outcropping granites and schists.

Thus, if the principle be accepted that abyssal injection implies precedent geosynclinal sedimentation and diastrophism, we can infer from the presence of these massive granites the deposition and folding of an Early Proterozoic sedimentary series, of which no traces remain upon the present surface.

*(b) The post-Silurian Granites of Tasmania.*

These, with their attendant basic and ultra-basic rocks, are by far the most extensive, and important economically, of the plutonic intrusions in the island-State. They were formerly referred to as the Devonian granites, for what reason it is not quite clear, but possibly because of a supposed correlation with the Victorian granites and granodiorites, which were tentatively regarded as early-Devonian. If the correlation stands, then in view of recent discoveries

as to the age of the Victorian rocks<sup>35</sup> the Tasmanian granites should now be considered to be late-Devonian. But in 1921 Hills<sup>36</sup> gave it as his opinion that they were epipelagic Silurian, and the question arises as to which view is correct.

If it be agreed that granite batholiths are always injected under and through just-folded geosynclinal sediments, then, since no Devonian strata whatever are known to outcrop in Tasmania, it would be unsound to argue for a late-Devonian age for these granites, unless indeed magmatic peculiarities are sufficiently marked to warrant definite correlation with the late-Devonian intrusions of the mainland. Unfortunately the petrology of the Tasmanian granites has not been worked out sufficiently to permit of detailed comparison, and in the circumstances it is most natural and logical to assign tentatively to these rocks a late-Silurian age, inasmuch as the youngest strata into which the granites are intrusive are the folded Silurian. If at some future date comparative petrology can establish consanguinity between these rocks and the late-Devonian intrusions of Victoria and New South Wales, then a strong case will have been made out for the former extension of the Devonian sea to Tasmania, though all its deposits have since disappeared.

(c) *The Permo-Carboniferous Granites of Eastern Australia.*

There is another rather interesting and important palaeogeographical problem on which some light may be shed by a consideration of the distribution of batholiths, namely the former extent of the area of deposition of Permo-Carboniferous strata in this State. At the present day the principal area where these strata outcrop is that forming what is called by the State Geological Survey the Main Coal Province, a broad belt extending in a N.N.W.-S.S.E. direction for over 200 miles, and stretching along the coast from Newcastle to the Clyde River. Scattered but considerable

outcrops occur in the north and north-west of the New England plateau, as about Drake and Ashford, and another occurrence centres round Kempsey in the south-east of New England; everywhere the strata are to a greater or less extent folded. The New England plateau is composed largely of ancient, more or less metamorphosed sediments, possibly in part Ordovician, broken through by bathyliths of granitic rocks which have been shown<sup>37</sup> to be in places intrusive through strata of Permo-Carboniferous age. The main outcrops of plutonic rock are found in the western and central parts of the plateau, and have been traced as far south as Tamworth and Nundle, and even to the Barrington plateau; scattered outcrops also occur to the east, extending over to the coast. To the north the granites continue across the border into Queensland, where they invade the Permo-Carboniferous beds to the south of Warwick.

It has been assumed by some authorities that the present eastern and western boundaries of the Main Coal Province (which are roughly parallel) coincide approximately with the original limits of a Permo-Carboniferous geosyncline, which was bounded to the east by highlands, composed of old rocks, separating it from an eastern area of deposition. Such a conception appears very definitely in the writings of Sir Edgeworth David<sup>38</sup> and E. C. Andrews.<sup>39</sup> A. B. Walkom<sup>40</sup> in discussing the matter likewise considers an area roughly north from Nundle to Inverell and eastwards to Hillgrove to have been land throughout Permo-Carboniferous times; the present surface-rocks of this area are mostly granites and old slaty rocks. Benson,<sup>41</sup> however, in 1923 published a palaeogeographical map showing the whole area between the Main Coal Province and the present coastline as a site of Permo-Carboniferous deposition, but without discussing the palaeogeography in detail. Bryan<sup>42</sup>, in 1926, tacitly adopted Benson's views.



It is clear, therefore, that there is no unanimity in regard to the distribution of Permo-Carboniferous land and sea in New South Wales.

Now the Main Coal Province is bounded on its eastern side by Mesozoic or Early Tertiary faults which have raised the older rocks to the east by more than 5000 feet in places as compared with the Permo-Carboniferous strata, and it is, therefore, at least probable that these latter originally extended much further to the east than at present, especially as there are quite considerable thicknesses of strata still showing right up to the fault-planes. Erosion following quickly on the faulting would account for the present absence of the younger rocks on the eastern or upthrow side.

But quite apart from this, if we are to accept the evidence of the granites, then, since they are mainly late Permo-Carboniferous in age, it is necessary to postulate an area of deposition once extending well over to the east of the Main Coal Province, and a study of the geological map suggests strongly that Permo-Carboniferous sediments, freshwater or marine or both, once completely covered what are now the northern and central parts of the New England Plateau, perhaps as far east as the coast, and that on the south they extended continuously across from the Main Coal Province to Kempsey, even as Benson has indicated. In Queensland, according to the map accompanying Skeats' paper<sup>33</sup>, the Permo-Carboniferous granites extend northwards along a broad coastal strip to within 120 miles of Cape York. It would follow, if this is correct, that both Benson and Bryan in their palaeogeographical maps might have extended the site of the Permo-Carboniferous sedimentation northward almost to the most northerly point of Queensland.

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THE AMOUNT OF HYDROCYANIC ACID IN  
SORGHUM, SUDAN GRASS AND SOME  
HYBRIDS.

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and

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*(Read before the Royal Society of New South Wales, Sept. 2, 1931.)*

The object of the experiments detailed in the present paper was twofold, firstly, to ascertain the variation in the amount of hydrocyanic acid exhibited by different varieties of sorghum, and secondly, to determine to what extent it might be possible, by crossing sorghum with sudan grass, to breed hybrids containing a smaller amount of hydrocyanic acid, and thus reduce the danger to stock that is now incurred when fed on this valuable fodder. Although the original programme has been curtailed by the cessation of financial assistance to the Poison Plants Committee by the Council of Scientific and Industrial Research, it is the intention of this Committee to continue these experiments during the coming season.

It is now about thirty years since Dunstan and Henry<sup>1</sup> showed that when sorghum was cut or bruised, contact was made by the enzyme and the glucoside, with the result that hydrocyanic acid was immediately evolved. They also succeeded in isolating the glucoside which they termed dhuririn from the native Egyptian name of the plant, and showed that in addition to hydrocyanic acid, it gave on decomposition, 1,4 hydroxybenzaldehyde and glucose. These

<sup>1</sup>J—September 2, 1931.

observations were accompanied by the equally valuable one that the production of hydrocyanic acid increases with the development of the plant and then rapidly diminishes. Such questions then arose whether all varieties were equally toxic and whether the plant could be rendered innocuous by drying or by other means. One of the early workers on these problems was J. C. Brunnich, of Brisbane, who in 1903<sup>2</sup> made an investigation of two varieties of sorghum, viz., Planter's Friend or Imphee and Early Amber, and found the amount of hydrocyanic acid varied in the fresh plant from 0.027 to 0.035 and 0.011 to 0.014 per cent. respectively for the two varieties named, the higher figure in each case being obtained from the manured plant, at the same time confirming the decrease in hydrocyanic acid as the plant developed.

In 1912, Schroder and Dammann<sup>3</sup>, working at Monte Video, examined three varieties of sorghum grown in Uruguay, and found the following amounts—from the variety *saccharatum*, 0.030; *vulgare*, 0.020 and from *halapense*, 0.014 from 100 grammes of the fresh plant. These quantities decreased as the plant matured, but the acid did not disappear entirely; there was an increase of 33 to 100 per cent. in manured plants.

Two American investigators, Willaman and West<sup>4</sup>, in 1915, examined a number of sorghum plants and obtained a maximum of 83 milligrams per 100 grammes, calculated on a dry weight basis of the whole plant, which at that time was 18 inches high. After 62 days the plants had attained a height of 61 inches and then contained a negligible amount of hydrocyanic acid. In the following year<sup>5</sup> they maximum of 114 milligrams when the plant was 14 inches high, whilst there was only a trace when the height had increased to 78 inches after 92 days growth. A few years

carried out a similar series of experiments and found a later, Dowell<sup>6</sup>, working at Oklahoma Agricultural Station, found one sorghum of 32 inches growth gave 22.2 milligrams and 22.8 milligrams (second growth), calculated on the fresh plant. Menaul and Dowell<sup>7</sup> obtained from fresh sudan grass 15 inches high, 10.5 milligrams, equivalent to 57.9 milligrams on the dry weight, the amount becoming less on later growth. In 1919,<sup>1</sup> Colleson<sup>8</sup> working in Florida, examined twenty-one varieties of sorghum and found that they contained from 0 to 3.8 milligrams of acid, Dwarf Hegari and Feterita being the varieties containing the largest amount. Swanson at Kansas Agricultural College in 1921<sup>9</sup>, reported "large amounts" of hydrocyanic acid in sudan grass, and later<sup>10</sup> determined the amount present under various conditions. Practically the whole of the acid was yielded by the leaves and the maximum was found to be from a whole plant 4 inches high, this being 20 milligrams. There was a loss on drying, but the acid did not entirely disappear after wilting for 5 days. This plant gave less acid than sorghum or kafir. In 1923, Brunnich<sup>11</sup> reported on the various sorghums at different stages of growth. There was much variation in the hydrocyanic acid at three weeks and later cuttings showed greatly reduced amounts.

Recently the analyses of nine hybrids have been published by Ramsay<sup>12</sup>, these were bred from Saccaline sorghum as the male and sudan grass as the female. Some plants were examined when 4 feet high, but most of them were 12 to 18 inches high. The amount of acid varied from nil to 11 milligrams per 100 grammes, the largest amount being obtained from a 4 feet hybrid. Pure sudan grass, height not stated, gave only 0.01 milligrams and pure saccaline, 3 milligrams. In this connexion it should be

noted that as neither the method of analysis nor the condition of the material was stated the results obtained emphasize the importance of further investigations.

### EXPERIMENTAL.

The plants used in these experiments were sown at the Glenfield Veterinary Research Station on October 15th, 1928. For the necessary arrangements the authors are indebted to the Director, Dr. Seddon, who has kindly supplied the following particulars. Altogether, 18 sowings in numbered rows were made. These consisted of eight sorghum-sudan grass hybrids, varieties of sorghum and one row of sudan grass. The seeds of 6 hybrids had been obtained in 1926 from Mr. A. N. Whittet, N.S.W. Government Agrostologist, those numbered 1 and 6 in the Table, had been grown on unbagged heads, whilst Nos. 2 to 5, inclusive, were from bagged heads. The remaining two hybrids had been obtained from the same source in the month previous to sowing.

The determinations of hydrocyanic acid were made at various stages of growth, the age of the plant in days being shown in the table. Before carrying out quantitative measurements each sample was tested qualitatively by cutting up about 1 gramme finely with scissors and macerating in water in a closed test tube, the colour imparted to a sodium picrate paper being taken as an indication of the presence of hydrocyanic acid, which was then determined, some of the qualitative tests being carried out at Glenfield within half an hour after gathering the specimens.

### Method of Estimation.

It seems more than probable that some of the results quoted above are not strictly comparable, for, in some cases, there is no information as to the moisture in the material

examined, nor of the method employed, so although the results of each worker may be consistent in themselves, they cannot necessarily be compared with those of other workers. Such factors as the possibly incomplete hydrolysis of the glucoside, the difficulty in removing the hydrocyanic acid when formed, and the possible existence of various combinations of hydrocyanic acid with other constituents of plants have all been shown to be important factors in this connexion. Swanson showed that the maximum yield was obtained from sorghum by macerating for 6 hours or overnight at room temperature, and this procedure was adopted. Several whole plants, exclusive of roots, were passed through a meat mincer in order to obtain a thoroughly representative sample. Twenty grammes of this were macerated in a tightly closed flask with 300 cc. of distilled water overnight at room temperature. The contents of the flask were then distilled in steam until all the hydrocyanic acid had been removed, the distillate being collected in an excess of decinormal sodium hydroxide. This was then made acid with hydrochloric acid and titrated with decinormal iodine in the presence of sodium bicarbonate. Under these conditions 1.4 hydroxybenzaldehyde which is also a product of the reaction was found to be non-volatile in steam and therefore did not affect the result.

Parallel with the estimation, when sufficient of the sample was available, the moisture lost on air drying was recorded,\* twenty grammes of the disintegrated material being set aside until the weight was constant. The time required for this varied from eight to fourteen days.

\* In later experiments with other plants it has been found preferable to dry at 100° to constant weight and in further work on sorghum this modification will be made.



THE AMOUNT OF HYDROCYANIC ACID IN SORGHUM AND  
ALLIED PLANTS FROM SEED SOWN AT GLENFIELD V. R. S.  
ON 15/10/'28.

		Number of Milligrams of HCN in 100 grams of—											
		Fresh Plant.				Air-dried Plant (calculated).				Air-dried Plant (found)			
Age of Plant in days	..	42	64	90	97	42	64	90	97	42	64		
Size in inches	...	6-12	20	60	60	6-12	20	60	60	6-12	20		
Name, Row and No													
Sorghum sudan hybrid—													
1	I	—	21	—	18	—	99	—	43	—	41		
do.	1 2	—	27	5	17	—	157	19	44	—	98		
do.	1 3	37	22	13	20	181	116	44	78	129	43		
do.	1 4	—	18	14	16	—	81	75	62	—	44		
do.	1 5	—	—	—	—	—	—	—	—	—	—		
do.	1 6	—	21	15	12	—	98	47	34	—	55		
do.	2 7	2	7	5	5	12	34	15	14	10	12		
do.	2 8	—	13	8	10	—	58	20	28	—	28		
Saccaline 3 and 4	..	36	11	4	8	172	57	23	30	121	48		
Collier 5 and 6	...	54	19	2	6	262	101	14	26	153	52		
White African 7 and 8	..	53	45	6	6	282	223	29	40	160	—		
Sumac 9	..	44	35	11	14	243	160	37	42	140	54		
Cowper 10 and 11	..	36	25	12	8	192	129	53	39	144	62		
Sudan Grass 12 and 13	..	9	12	4	3	—	43	13	10	—	35		
Number 34	14	33	31	4	9	145	169	12	39	112	52		
Feterita 15 and 16	...	111	75	20	23	—	331	67	73	—	138		
Milo 17 and 18	...	50	33	8	19	248	163	25	73	185	57		
Gooseneck 19	...	—	69	8	19	—	291	32	72	—	137		

All the above were free from HCN 132 days after sowing.

From the percentage of moisture and of the hydrocyanic acid yielded by the fresh plant, the amount obtainable from the dry material was calculated. Of the specimens collected in November and December actual determinations of the hydrocyanic acid in the dry plant were made, but in the samples gathered later this was so small that its amount was not considered of sufficient interest. The results are set out in the table.

#### CONCLUSIONS.

1. All the varieties examined yielded some hydrocyanic acid up to about 130 days after sowing, when the seeding stage had been passed, but the amounts varied considerably. Some gave larger percentages than have hitherto been recorded, sudan grass gave the least and feterita the most.

2. Owing to slow germination only two of the eight hybrids were available at the time of the first examination, but from the second series of results it seems that these hybrids are lower in hydrocyanic acid, at all events, in the first month or two, than the majority of the sorghums.

3. The results of other workers have been confirmed in that the percentage of hydrocyanic acid has been found to be greatest in young plants and to diminish as growth proceeds.

4. Under the conditions specified the loss of hydrocyanic acid on exposure to the air, varied from 14 to 65 per cent. These two particular specimens still contained when air dry, 48 and 54 milligrammes of hydrocyanic acid per 100 grammes, and reference to the table will show that other specimens yielded higher results than these. As Seddon and King<sup>13</sup> have shown that, in the presence of sufficient enzyme, as is the case with the sorghums examined, a quantity of 50 milligrammes, per 100 grammes in the dry plant is likely to render it toxic, it would appear that young

sorghum, even when wilted, cannot always be considered safe as fodder.

It is desired to acknowledge a grant from the Council of Scientific and Industrial Research to the Poison Plants Committee, that has enabled one of us (C.B.C.) to participate in this work.

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Δ CONTRIBUTION TO THE CHEMISTRY OF THE  
FRUIT OBTAINED FROM THE WHITE CEDAR  
TREE (*Melia Azedarach*, L. var. *australasica* (DC.) Syn.  
*Melia australasica*, A. Juss.) GROWING IN NEW  
SOUTH WALES, WITH NOTES ON ITS REPUTED  
TOXICITY.\*

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(Read before the Royal Society of New South Wales, Sept. 2, 1931.)

The information recorded in this paper embraces the results of an investigation undertaken in 1922, for the purpose of ascertaining the chemical composition of the fruit obtained from the White Cedar Tree growing in New South Wales. At the same time, in view of the fact that cases of apparent poisoning had previously been observed and recorded in both human beings and animals after eating the fruit, it was realised that the isolation and identification of the supposed toxic constituent was an urgent necessity. This fact was emphasised during the progress of the work by reports of additional cases of poisoning having occurred at that time, and indicated the necessity for concentration for the time being on that particular portion of the investigation. Curtailment of the original work undertaken naturally followed, and later, owing to pressure of official work, it was found impracticable to complete the investigation, both in regard to the chemical composition of the fruit, and identification of the toxic constituent, as was

\* Toxicity tests conducted by R. GRANT, F.C.S., formerly Assistant Microbiologist, Department of Public Health, Sydney.

originally intended. The matter has been held in abeyance since 1927, but, owing to numerous enquiries recently received by the Institution regarding the toxicity of the fruit, and in order that later workers in the same field of investigation might become acquainted with what had already been done, it was considered advisable to publish, without further delay, the results obtained.

In order to facilitate the isolation of the toxic principle of those fruits which were reputed to be poisonous, Mr. R. Grant, F.C.S., then Assistant Microbiologist of the Department of Public Health, Sydney, through the courtesy of the Director General of Public Health, kindly undertook feeding experiments on guinea pigs, utilising the several portions constituting the fruit, e.g., meal, skin, seeds, etc., in addition to extracts prepared therefrom. As a result of these practical tests it was hoped that the particular portion of the fruit containing the toxic principle would be speedily indicated.

A large number of feeding tests was conducted over a period of about five years, with varying, and often disappointing, results. The fact, however, appears to be established that, when present, the toxic constituent occurs in the resinous portion of the fruit, and further, that a substance of alkaloidal nature exists in the resin. Evidence was also obtained that, whereas neither the alkaloidal portion of the resin, nor the resin from which the former was extracted, proved toxic when administered alone, a mixture of both produced fatal results.

It was found, however, that, whilst fruit obtained from trees growing in certain localities (Parramatta and Dubbo) contained the toxic principle, that obtained from trees growing in another locality (Grafton) proved harmless when eaten, and this variation was at first thought to be

due to seasonal changes, soil conditions, or other causes; according to information kindly furnished by Mr. E. Cheel, Curator of the National Herbarium, Botanic Gardens, Sydney, however, the occurrence of at least two forms of the species might readily account for the varying results obtained.

Analogous cases are to be found in Australian essential oil yielding species; the occurrence of varieties of a particular species, all botanically identical, but differing in the chemical composition of the oil present in the leaves, has been brought to light during recent researches carried out at this Institution. (Proc. Royal Society of New South Wales, 1922, Vol. 55, pp. 82-87; 1927, Vol. 61, pp. 54-67; 1930, Vol. 64, pp. 264-297.)

With regard to the White Cedar, the following extract from a letter written by Dr. John MacPherson, of Sydney, is of special interest:—

“My friends in the country inform me that the domestic fowls and turkeys eat up all the fallen ‘berries’ with avidity without sustaining any harm. But they noticed a curious thing, namely, that of three trees together, all bearing profusely, the Black Magpies stripped one tree bare and never touched the fruit of the others.”

As set forth under “Experimental,” fruit from trees growing at Grafton, Dubbo, and Parramatta respectively, in New South Wales, were examined, and later, a parcel of fruit from trees growing at Richmond, New South Wales, was also tested for toxicity.

#### **Previous Observations Regarding Toxic Properties of White Cedar Fruit.**

The late Mr. J. H. Maiden in “Forest Flora of New South Wales,” Vol. 3 p. 93, cites a number of cases of poisoning having followed the eating of White Cedar Fruit by both humans and animals; pigs appeared to be par-

ticularly susceptible, and a number of fatal results followed the eating of the fruit.

An examination of fruit for the presence of hydrocyanic acid was carried out by F. B. Guthrie (Agricultural Gazette of New South Wales, 1897, p. 700) but none was detected.

#### Description of Tree.

The species *Melia Azedarach* L. Var. *australasica* C.DC. (Monogr. Phan. i 1878, 452); Syn. *Melia australasica*, A. Juss, is described by Bentham in "Flora Australiensis" (Vol. 1, 380), and is also figured and described by J. H. Maiden in "Forest Flora of New South Wales," Vol. 3, p. 93. The tree is stated to reach a height of 40-60 feet, and "its habitat extends from a little north of Sydney along the coast and coastal districts to North Australia." The tree responds readily to cultivation, and some of the fruit used in the present investigation was obtained from cultivated trees.

#### Description of Fruit.

The ripe berry or drupe consists of a hard, ribbed seed (the ribs varying in number from four to seven) surrounded by a pasty, sticky pulp, the whole being enclosed in a rather tough, golden-yellow skin. The odour is "sharp" and characteristic. The taste is at first sweet, but immediately afterwards becomes decidedly bitter. Prior to ripening, the firm, green berry contains a milky emulsion. Those obtained from trees growing at Grafton, New South Wales, were ovoid in shape, whilst the berries from trees growing at both Dubbo and Parramatta in the same State, were more spherical or globose than the Grafton berries. One hundred ripe berries chosen at random from the Grafton consignment weighed 67 grams, equivalent to an average mass of 0.67 gram. The dimensions of the smallest berries averaged 12 mm. long by 8 mm. short diameter, and mass

0.3 gram; the largest averaged 18 mm. by 11mm. and mass 1.07 gram;; whilst the medium sized berries averaged 16 mm. by 11 mm. and mass 0.7 gram.

### Composition of the Fruit.

The results of the chemical analysis of the ripe fruit, show that the principal portion, i.e., the pulp, comprises a meal consisting largely of starch, an oil, a resin, and a reducing sugar, identified as dextrose. Water-soluble substances of acid nature are also present. The hard seed contains a number of small kernals which yield a fixed oil. A tough skin encloses the fruit.

The moisture content of ripe berries from various parcels received, varied from 18% to 29%.

### EXPERIMENTAL.

The majority of the work to determine the chemical composition of the ripe fruit was performed on a parcel of fruit obtained in July, 1922, from trees growing at Grafton, New South Wales, which parcel was kindly supplied by Mr. Eugene Rudder. This gentleman has devoted much time and energy to the utilisation of White Cedar berries, and acknowledgment of his efforts is gladly recorded.

The abovementioned parcel of fruit, after removal from the stalks, weighed 15½ lbs.

*Extraction of fruit by Solvents.*—The skin of each berry was broken in order to facilitate extraction of soluble matter by solvents, and the fruit placed in a vessel, and covered with cold ethyl ether; after standing for three weeks, the ethereal solution was poured off, the fruits washed with a small quantity of fresh ether (which was added to the ethereal solution), and the fruit allowed to stand in contact with cold 95% alcohol for two months. The alcoholic solution was then removed, and after washing with the same solvent, the fruit was treated with boiling water, which



treatment separated the insoluble portion of the pulp (meal) from the seed, and also dissolved the remaining soluble constituents of the pulp. The meal was separated by filtration, washed with water and dried. Separation of the skins from the seeds was effected by rubbing the fruit between the palms of the hands under water, whereby the seeds sank to the bottom of the vessel and were collected, whilst the skins were suspended throughout the liquid, and were recovered by filtration.

*Proximate analysis of Grafton fruits.*—As a result of the previously described treatment, the following approximate percentage composition of the Grafton fruit was obtained:—

	Per cent.
Ethyl ether-soluble extract . . . . .	3
Alcohol-soluble extract . . . . .	7
Water-soluble extract . . . . .	20
Meal . . . . .	4
Skin . . . . .	5
Seeds . . . . .	41
Moisture in original fruit . . . . .	20
	<hr/>
	100
	<hr/>

For purposes of comparison, and in order to show the variation in composition, the proximate analysis of a parcel of fruit obtained in June, 1923, from trees growing at Dubbo, New South Wales, is appended:—

	Per cent.
Petroleum-ether extract . . . . .	0.2
Ethyl ether-extract . . . . .	0.6
Chloroform-extract . . . . .	0.7
Alcohol-extract . . . . .	7.0
Water-extract . . . . .	18.3
Meal . . . . .	4.0
Skin . . . . .	4.7
Seeds . . . . .	46.5
Moisture in original fruit . . . . .	18.0
	<hr/>
	100.0

*Note.*—The above analysis was carried out by extracting fifty berries, weighing 42 grams, in a Soxhlet apparatus with the first four solvents successively; the water soluble portion was obtained by agitating the berries from the above treatment with cold distilled water until all soluble matter had been removed. The meal, skins and seeds were recovered as previously described in the treatment of the Grafton berries.

*Ether Extract of Grafton fruit.*—The ethereal solution from 15½ lbs. of fruit was concentrated to small bulk by distillation of the solvent, and at this stage a small quantity of white nodules separated from the concentrated solution; these were removed by filtration, and washed with cold ether. The concentrated ether solution was poured into a shallow dish, and the last traces of ether removed by gentle heat. On cooling, a turbid, yellowish, resinous mass remained which possessed the characteristic odour of the ripe fruit. The weight of the material was 213 grams.

*White nodules separated from concentrated ethereal extract of fruits.*—The white nodules were crushed and recrystallised from boiling ether in which they were sparingly soluble. The crystalline material melted at 192-205° C. in an open capillary tube, and at 205-210° in sealed capillary tube (in sulphuric acid bath). The substance did not reduce Fehling's solution, and when boiled for some time with weak sulphuric acid, and again tested with Fehling's solution, a negative result was obtained. It does not appear, therefore, to possess glucosidal properties.

*Resolution of ether extract into Fat and Resin.*—A portion of the ether extract (111 grams) was triturated with two successive portions of petroleum ether (b.pt. 32-50° C.), until all soluble material had been extracted; the solution was filtered, and on removal of the solvent,

59 grams of clear, pale-yellow viscous oil were obtained.

The insoluble material consisted of 49 grams of brittle resin, which was readily crushed to a light-yellow powder.

*Analysis of oil.*—The oil possessed a “resinous” odour, and after standing for some time, became turbid; it also possessed a slight “tackiness” when tested between the finger, thus indicating the presence of resin. Portion of the oil (48 grams) was agitated with two successive portions of 100 c.c. alcohol, which solvent dissolved the resin, and after separation of the alcoholic solution, 32 grams of clear, viscous oil were recovered which possessed a slight odour and bland taste.

On removal of the alcohol from the separated solution, 14 grams of a clear, tacky resinous mass were obtained, which apparently contained a proportion of the oil in admixture. The following physical and chemical characteristics are those of the oil before, and after, treatment with alcohol:—

	Before (49 grams).	After (32 grams).
$d_{15}^{15}$	0.9735	0.9523
$n_D^{20}$	1.4930	1.4845
Acid Value	9.1	8.4
Saponification Value	150.6	164.9
Iodine Value (Wijs, 2 hours)	145.05	150.7

*Mixed fatty acids.*—A portion (21.3 grams) of the 32 grams of oil was saponified with alcoholic KOH and the resulting soap agitated with ether; 3.6 grams of unsaponifiable material were obtained which were again treated with alcoholic KOH, and the unsaponifiable material removed by ether; 2.95 grams of a light-yellow, clear, resinous mass were obtained, thus indicating that portion of the resin had remained in the oil.

The soap solution was decomposed with dilute sulphuric acid and the liberated fatty acids washed with hot water until free from mineral acid. On cooling, 15 grams of a semi-solid crystalline mass of mixed fatty acids were obtained, which retained a resinous odour and slight "tackiness."

*Determination of Resin acids in mixed Fatty acids.*—The method of Twitchell described by Dieterich in "Analysis of Resins" (1930, p. 49) was employed, with the following result:—

0.6774 gram mixed acids gave 0.1040 gram resin acids  
= 15.35% resin acids.

It is thus apparent that the oil still contained a considerable proportion of resin.

*Separation of "liquid" and "solid" fatty acids.*—The mixed fatty acids were resolved into "liquid" and "solid" acids by the lead salt-ether method. The following constants were obtained for the respective acids:—

"Liquid" acids.	"Solid" acids.
Neutralisation value, 132.4	Melting point, 55°C.
Mean molecular weight, 314.	Mean molecular weight, 274.
Iodine value (Wijs, 2 hrs.) 119.4	

*Bromides of "liquid" acids.*—A portion (5.6 grams) was dissolved in 50 c.c. dry ether, the solution cooled to  $-20^{\circ}$  C., and saturated with bromine; after 24 hours a minute quantity of precipitate was observed, but this was too small to handle. The ether was allowed to evaporate, and the pasty mass triturated with light petroleum ether at  $-20^{\circ}$  C.; very little appeared to dissolve, and the solution was decanted from the insoluble resinous portion. A clear, viscous, light-yellow liquid was recovered from the petroleum ether solution after allowing the solvent to evaporate. The proportion of bromide present was deter-

mined by boiling with concentrated nitric acid and solid silver nitrate.

0.3796 gram liquid bromide gave 0.3384 gram AgBr. = 37.93% Br. The bromide of oleic acid contains 36.18% of bromine.

*Elaidin test.*—Portion of the original liquid acid, which possessed an odour of oleic acid, yielded a pasty, orange coloured mass when treated with sodium nitrite and nitric acid.

The liquid fatty acid apparently consists of oleic acid.

*“Solid” acids.*—Efforts to resolve the crystalline “solid” acids into their separate constituents were not successful, owing to the small quantity available. A consideration of the melting point, and mean molecular weight, however, indicates that they consist of a mixture of palmitic and stearic acids.

*Resin from ether extract.*—The light yellow, brittle resin, after crushing to a fine powder, and thoroughly drying in the desiccator, possessed a characteristic odour, and gave the following figures on analysis:—

Melting point (taken on cover glass over mercury) 102°C.  
 “ “ in capillary (in sulphuric acid bath)  
 agglutinated at 80°C, melted completely at  
 100-105°C.

Specific Gravity of fused resin . . . . .	1.1533
Acid value . . . . .	17.7
Saponification value . . . . .	155.82
Iodine value (Wijs, 2 hours) . . . . .	117.6 (approx.)

The resin fused to a clear, yellow viscous liquid on the water bath, and, on cooling, formed a clear, golden-yellow, glassy mass. Its solubility in various solvents was determined approximately, with the following results:—

Hot or cold petroleum ether (b.p. 32-50°). Almost insoluble.	
Absolute alcohol . . . . .	} Soluble.
95% alcohol . . . . .	
Chloroform . . . . .	
Ethyl ether . . . . .	

Benzol .. .. .	Moderately soluble.
Hot or cold turpentine ..	Very sparingly soluble.
Amyl alcohol .. .. .	Soluble.

Treatment of a fragment of the resin with concentrated sulphuric acid gave a dark red colour, changing to a dark brown. A solution of the resin in alcohol gave, with ferric chloride, a greenish colouration.

*Saponification of resin.*—Ten (10) grams were saponified by boiling with 3 grams potassium hydroxide in 60 c.c. alcohol for one and a half hours, the solution poured into water, and the watery solution extracted with ether; on removal of the ether from the extract, 3.3 grams of a light yellow, brittle resin were recovered. It was redissolved in ethyl ether, and petroleum ether (32-50°C) added until the solution became faintly turbid, and set aside for two days, when the solvent evaporated and crystals appeared throughout the resinous mass. Efforts to recover the crystalline material were not successful.

The aqueous solution was concentrated to small volume on the water-bath, and decomposed with dilute sulphuric acid, the resin acids separating as a brown viscous mass; it was washed with hot water until free from mineral acid, and dried; 4.2 grams of dark brown, "tacky" acid being obtained. It gave a neutralisation equivalent of 102.1.

The aqueous liquid from which the resin acids had been separated was neutralised with potassium hydroxide, concentrated to small volume on the water bath, and extracted with ether. The ethereal solution was separated, and the solvent removed; 0.0254 gram of viscous, brownish coloured material, possessing a phenolic odour was thus obtained. Its solution in alcohol gave a dark red colour with concentrated sulphuric acid, but ferric chloride produced no colouration.

No further work was carried out on the resin.

*Alcoholic extract of fruit* (after ether treatment).—The alcohol was removed from the solution by distillation under reduced pressure, and the resulting product was a dark, reddish-brown solution in water (originally present in the fruit). It possessed a sweet, followed by a bitter, taste, and was decidedly acid in reaction. The solution was agitated successively with petroleum ether, ethyl ether, and chloroform, but traces only of resinous bodies were extracted. Treatment with basic lead acetate solution gave a yellow precipitate, which was filtered off, washed, suspended in water, and decomposed with sulphuretted hydrogen. The resulting filtrate from the lead sulphide was tested for organic acids, etc., but no definite result was obtained.

The filtrate from the original lead acetate precipitate, was treated with sulphuretted hydrogen to remove any lead salt present, and concentrated to a thin syrup under reduced pressure. On warming a small quantity of the syrup with sodium hydroxide, ammonia was freely evolved. The syrup possessed a sweet taste, and gave a flocculent, almost white precipitate, with phosphotungstic acid in the presence of sulphuric acid. No definite result was obtained on examination of this precipitate.

*Osazone*.—Portion of the solution was taken and an osazone prepared in the usual manner; the derivative was recrystallised from 50% alcohol, and the characteristic crystals melted at 206°. The reducing sugar, dextrose, is, therefore, present.

Fehling's solution was readily reduced by the syrup.

In order to determine if the sugar was originally present in the fruit as dextrose, a few of the fresh ripe berries were placed in distilled water for a few hours; the aqueous solution was filtered and portion tested with Fehling's solu-

tion when a marked reduction of the copper sulphate solution occurred. An osazone was prepared from a portion of the aqueous solution, and, after, recrystallisation, melted at 206°C.

*Water extract of Fruit (after alcohol treatment).*—The fact that boiling water was used principally for the purpose of obtaining the meal, skin and seeds in a clean condition, militated against the examination of this extract owing to changes which would probably occur at that temperature. The solution was treated with basic lead acetate, but nothing definite was obtained from the precipitate thrown down. An osazone was prepared from the filtrate after freeing from sulphuretted hydrogen, and, after recrystallisation, melted at 207°C. (osazone of dextrose).

*Fixed oil from seeds.*—The seeds, after complete separation of the pulp, and subsequent drying, weighed 2828 grams. These were passed through a disintegrator in order to break the shells and expose the kernels (the latter are contained in longitudinal cavities in the shells, and vary in number from 2 to 6 in each seed). Owing to the smallness of the kernels, it was found impracticable to separate them from the shells, and the broken seeds were allowed to stand in contact with cold ethyl ether until all soluble matter had been removed; the ethereal solution was then separated from the seeds, the solvent removed, and 30 grams of a heavy, brown viscous oil of "acidic" odour obtained. The oil possessed the following characteristics: -

$d_{15}^{15}$	0.9534
$n_D^{20}$	1.4787
Acid Value	71.5
Saponification Value	194.9
Iodine No. (Wijs, 2 hours)	128.1



*Meal*.—The dried, finely ground meal possessed a “cereal-like” odour, and a dirty brown colour. A portion of the meal was boiled with water, the liquid allowed to cool and a solution of iodine added; the deep blue colouration produced showed the presence of starch. Microscopical examination of the meal revealed minute granules which were stained blue with very dilute iodine solution. Cellular material other than starch was also observed through the microscope.

*Skins*.—Beyond drying, grinding (for feeding experiments) and weighing the skins, they were not further examined.

#### INVESTIGATION OF TOXIC PRINCIPLE OF FRUITS.

As previously mentioned, the various portions of the fruit, as well as solvent extracts, were submitted to Mr. R. Grant for the purpose of carrying out feeding tests on guinea pigs; the portion or portions of the fruit which produced poisoning could then be examined carefully with a view to isolating the toxic constituent.

During the period 1923-1928 over one hundred feeding tests were conducted, and in each case where toxic symptoms were observed, or death resulted, the test was repeated on a fresh animal.

#### Fruit from Trees Growing at Grafton, New South Wales.

The following portions of the fruit were separately administered to the animals, but in no case were toxic symptoms observed:—

Whole fruit (seed broken); skins; meal; kernels of hard seeds; oil from pulp; oil from seed kernels; resin; white nodules separated from ether extract; hot and cold alcoholic extracts of the fruit.

A second parcel of fruit from Grafton gave similar non-toxic results.

**Dubbo Fruits.**

A viscous extract prepared by treating the fruits with boiling alcohol, and removal of the solvent by distillation under reduced pressure, produced toxic symptoms, and proved fatal. The post-mortem examination revealed evidence that the effects were somewhat similar to those produced by alkaloids of the strychnine type, viz.:—

20 10/26.—3 c.c. alcoholic extract Dubbo (14/10/26) siphoned into stomach at 11 a.m.

21st to 25th, animal active.

26th, animal sick; 27th, animal very sick with slight clonic spasms; 28th, animal in comatose condition; 29th, (9 a.m.) animal dead.

*Post-Mortem*.—Body rigid; all voluntary muscles deeply congested; spleen slightly so; both kidneys and surface vessels congested; no inflammation of stomach or small intestines; large intestine inflamed; caecum intensely inflamed.

Portion of the concentrated alcoholic extract was successively agitated with ether and chloroform, and after removal of the solvents, the small quantities of extract obtained were used in feeding tests. Both proved to be non-toxic.

**Fruit from a Number of Trees Growing at Parramatta.**

During the period covering the latter part of 1926, and the full year 1927, many collections of fruit, both ripe and unripe, were made, and experiments to isolate the toxic constituents, carried out.

*Ripe fruit*.—An extract was prepared, using boiling alcohol as solvent, and the latter was removed under reduced pressure. The dark viscous solution caused toxic symptoms, and death followed in seven days. A post mortem examina-

tion indicated poisoning effects of the strychnine type, and similar to those produced by the Dubbo fruit, viz.:—

20/10/26—3 c.c. siphoned into stomach at 11 a.m.

23/10/26, animal active; 25/10/26, animal sick; 26/10/26, animal very sick. Clonic spasms and rigors similar to those produced by strychnine.

27/10/26, animal dead.

*Post-Mortem*.—Body rigid, although dead several hours; voluntary muscles all deeply congested; liver congested; spleen slightly so; heart and lungs normal; both kidneys and surface vessels deeply congested; patchy inflammation in pyloric end of stomach; small and large intestines normal; caecum intensely inflamed. Absorption probably takes place in the caecum.

#### ATTEMPT TO ISOLATE TOXIC CONSTITUENT.

A portion (1 lb.) of fruits was sterilised in a moist atmosphere in the autoclave at a pressure of 2 lbs. of steam per square inch (in order to destroy enzymes which might decompose alkaloidal substances), the skins broken and the fruits agitated with a mixture of solvents and ammonia, as described by T. A. Henry in "Plant Alkaloids", 1913, p. 180. As a result of the treatment 0.1 gram of a brown amorphous residue with an odour resembling nicotine was obtained, which was dissolved in 1 c.c. of absolute alcohol and siphoned into the stomach of the animal. The material proved non-toxic. A further lot of fruit was similarly treated and a solution of 0.1 gram of the extract in 1 c.c. absolute alcohol allowed to stand until most of the solvent had spontaneously evaporated; it was then diluted to 2 c.c. with saline solution, and 1 c.c. of the liquid injected subcutaneously into the groin of the animal. Toxic effects did not follow.

*Treatment of hot Alcoholic Extract with "Floridin Earth."*—In order to determine if the toxic constituent might be recovered from the alcoholic extract by selective adsorption, a quantity of extract was prepared by treating 700 grams of the fruit with boiling alcohol, and agitating the cooled solution with a quantity of activated Floridin Earth (XXS grade) on the shaking machine for several hours. The Earth was recovered by filtration, washed with alcohol, and then thoroughly extracted with chloroform. A trace only of residue was obtained after removal of the solvent, which did not produce poisonous effects.

*Ethereal Extract of Ripe Fruits.*—Since the results obtained gave little indication of the actual source of the toxic constituent, it was decided to conduct feeding tests, using the ether extract of the fruit (which latter had previously been treated with light petroleum ether for removal of the fatty portion of the pulp). The solvent was removed from the ethereal extract and a light brown, tacky resin was obtained. About 0.5 gram was dissolved in 5 c.c. absolute alcohol, and 2 c.c. siphoned into the stomach of a guinea pig. The animal died in 24 hours, the symptoms and effects being similar to those of the previous tests which had proved fatal. The experiment was repeated on another animal with similar results, viz.:

16/3/27. 2 c.c. alcoholic solution siphoned into stomach at 2.25 p.m.; 9 a.m., animal very ill, no specific symptoms; 12 noon, Clonic spasms suggestive of brucine or strychnine poisoning; 2.30 p.m., animal dead.

*Post-mortem.*—All the muscular tissues had a pink tinge. Heart and lungs normal; large, blotchy haemorrhages in mucosa of cardiac end of stomach, contents of latter frothy and pale green in colour; intestine normal; caecum normal and contents fairly dry, normally they are "sloppy."

*Isolation of "Alkaloid".*—The ethereal extract (43 grams) was dissolved in 200 c.c. ethyl ether, and agitated with three successive portions of 20 c.c. of 0.5% sulphuric acid solution. The acid liquor was separated and a portion treated with Meyer's solution; a white flocculent precipitate was thrown down, this being the first chemical reaction indicative of an alkaloid obtained since commencing the investigation. After washing with a small quantity of ether, the acid solution was made alkaline with ammonia, and the fluorescent solution agitated with three successive portions of chloroform, separated, and the solvent allowed to spontaneously evaporate. A small quantity of resinous material was recovered which was dissolved in a small quantity of alcohol, and used in feeding tests. The material proved to be non-toxic. Portion of the resin from the above treatment was used in a feeding test and also gave a negative toxicity result.

Unfortunately it was not possible in this case to administer a mixture of the treated resin and the alkaloid (?) owing to the whole of the latter having been used in the feeding test.

**Treatment of Ethereal Solution of Resin (After Removal of "Alkaloidal" Body as Above) for Removal of Acid Constituents.**

The ethereal solution was washed free from sulphuric acid and agitated successively with the following aqueous solutions:—0.1% sodium carbonate, 1% sodium carbonate and 1% potassium hydroxide. In each case the alkaline extract was separated, washed with ether, and decomposed with dilute sulphuric acid; the liberated acid body was extracted with chloroform, and the solvent removed. In this manner the following products were obtained:—

*Extract with 0.1%  $\text{Na}_2\text{CO}_3$  Solution.*—1.4% of brown, viscous material of pleasant "acidic" odour.

*Extract with 1%  $\text{Na}_2\text{CO}_3$  Solution.*—3.6% dark, viscous, pleasant smelling material.

*Extract with 1%  $\text{KOH}$  Solution.*—8.2% dark, viscous material of pleasant odour. Its solution in chloroform exhibited a marked fluorescence.

The ethereal solution of the resin after the above treatment with alkaline solutions was washed free from alkali, and a golden yellow, tacky resin of pleasant odour recovered. A small portion of each of the extracts and the residual resin were used for feeding tests, all of which gave negative results for the presence of toxic bodies.

**Unripe Fruits from Parramatta, 22nd March, 1927.**

This parcel of fruit was obtained from a tree growing in the grounds of Messrs. Meggitt Ltd., Parramatta, New South Wales. The berries were almost spherical and the skins green, with the exception of a few which showed a slight yellow tinge, indicating the first stage of ripening.

The berries were bruised, and dried in air and sunshine; three pounds of dried fruit were thus recovered from 5lbs. 10ozs. of the fresh fruit (a determination carried out on 100 grams of the fruit by drying at  $100^\circ \text{C}$ . showed that the fruit contained 58.5% moisture). They were allowed to stand in contact with cold ethyl ether (previous extraction with petroleum ether was considered unnecessary) for ten days; the solution was poured off, and the solvent removed, when a small volume of green, oily emulsion, containing dark lumps of resinous material, was obtained. The liquid was poured through a filter cloth, the resinous lumps being retained on the filter. Both the oily filtrate and the resin (0.5 gram of each) were separately dissolved in small volumes of alcohol and used in feeding tests. As a result the oily filtrate was non-toxic, whilst the resinous portion killed in 24 hours, viz. :—

11/4/27.—2 c.c. alcoholic solution siphoned into stomach at 2.30 p.m.

12/4/27.—Severe convulsions followed by comatose condition. 12.30 p.m., animal dead.

*Post-mortem*.—Blotchy haemorrhages in the cardiac mucosa of the stomach; large haemorrhagic areas in the mucosa of the caecum; heart dark and congested; liver slightly pale; other organs normal.

*Isolation of "Alkaloidal" Substance*.—The remainder of the resin was dissolved in ether, and the solution extracted with successive portions of 0.1% sulphuric acid, a total of 100 c.c. of acid being used. The acid solution was separated, filtered, and on testing with reagents the following reactions were observed:—

<i>Reagent.</i>	<i>Result.</i>
Picric acid solution	Slight ppt. on standing.
I in KI	Heavy ppt. at once.
HgCl <sub>2</sub> solution	Slight ppt. on standing.
Meyer's solution	Moderate ppt. on standing.
Phosphotungstic acid	Slight ppt. on standing.
Ammonium persulphate	Slight ppt. on standing.

A portion of the acid solution was used in a feeding test, with non-toxic results. A portion (30 c.c.) was almost neutralised with decinormal KOH, the solution concentrated on the water bath almost to dryness, and the residue treated successively with ether and chloroform; practically nothing was dissolved by the solvents, and the aqueous solution was carefully evaporated to dryness on the water bath. The brownish residue, which contained crystals of potassium sulphate, was treated with absolute alcohol and the solution filtered; the solvent was allowed to spontaneously evaporate, leaving a very small quantity of yellowish residue.

Portion of a solution of the residue in alcohol was fed to a guinea pig with non-toxic results.

Since both the resin and the isolated "alkaloid" respectively failed to produce toxic results, it was suggested that a mixture of both might prove toxic. Accordingly 0.5 gram of the "alkaloid free" resin was dissolved in 5 c.c. of alcohol, and mixed with 5 c.c. of the alcoholic solution of the "alkaloid." This solution was used in feeding tests and produced toxic effects similar to those of the original resin.

It was thus apparent that administration of the resin together with the "alkaloidal" substance was necessary to bring about toxic results.

#### **Unripe Fruit from Parramatta, 5th May, 1927.**

This collection, from the same tree, represented portion of the same crop obtained in March, 1927. The berries were mostly green, a small proportion only having acquired a yellowish tinge; the pulp of the berries was softer and more "mealy" than that of the March collection. The moisture content was 52.5%. A quantity (15 lbs.), after bruising, was dried in the sunshine, and treated with cold ethyl ether for 8 days. On removal of the ether solution, a brown, aqueous solution separated at the bottom of the vessel. This was apparently derived from moisture remaining in the pulp.

The green ethereal solution was separated, concentrated to small bulk (50 c.c.) and transferred to an open dish, where it set to a gel on cooling. It was allowed to stand for three days, when 13.5 grams of a dark-green, tacky mass, which appeared to consist of a mixture of fat and resin, was obtained. This was dissolved in ether and the solution agitated with 0.1% sulphuric acid solution. The separated acid solution gave a precipitate with Meyer's



**solution.** The acid solution was almost neutralised with dilute KOH solution, a greenish coloured liquid resulting, which exhibited a blue fluorescence similar to that shown by dilute quinine solution. The solution was concentrated under reduced pressure (temperature not exceeding 60° C.) to about 20 c.c., a dark coloured resinous material, in addition to crystals of potassium sulphate, being deposited on the sides of the vessel. The contents of the vessel were removed with warm water, filtered, and the residue on filter paper, which appeared to consist of meal, washed with small quantities of warm water, these being added to the filtrate. The latter was carefully evaporated to very small bulk on the water bath, a dark resinous material separating out, the whole of which adhered to a glass rod when the liquid was stirred; the aqueous solution containing crystals of potassium sulphate was evaporated almost to dryness, the residue triturated with alcohol, filtered, and the alcohol allowed to spontaneously evaporate; 0.5 gram of brown resinous material being obtained.

The resin adhering to the glass rod was dissolved in alcohol, the solution filtered from adhering potassium sulphate, and the alcohol removed; 0.5 gram of brown resinous material being recovered. In addition to the above, 0.4 gram of resinous material adhering to the bottom of the vacuum distillation apparatus was recovered by washing the vessel with alcohol.

The three lots of "alkaloidal" resin were mixed together by dissolving in 20 c.c. alcohol. The original ether extract, after treatment with 0.1% sulphuric acid, was recovered from the ethereal solution, and 11.5 grams of a greenish-coloured, viscous mass obtained. This was agitated with 100 c.c. alcohol (the resin being dissolved, and the fatty portion remaining in suspension) and 10 c.c. of alcoholic

liquid mixed with 2 c.c. of the "alkaloid" solution; by this means a mixture was obtained which contained the two constituents in the same ratio in which they were present in the original ether extract.

Feeding tests were conducted with (1) 3 c.c. "alkaloid" solution, (2) 3 c.c. "non-alkaloidal" solution, and the abovementioned mixture of both. All three gave negative toxicity results.

*Oil from Kernels of above Fruit.*—The fixed oil extracted from a quantity of the broken seeds, after removal of skin and pulp, by extraction with ether, proved non-toxic.

**Fruit from Tree at Parramatta, 8th July, 1927.**

Both ripe and semi-ripe fruit was collected at the same time, and separately treated with ethyl ether. The resulting extracts were used in feeding tests, but in both cases proved to be non-toxic.

**Ripe Fruit Obtained from Tree Growing at Richmond,  
New South Wales.**

An ether extract obtained in the manner previously described proved to be non-toxic.

A concentrated alcoholic extract of the fruit was also non-toxic.

**CONCLUSIONS TO BE DRAWN FROM ABOVE EXPERIMENTS.**

As previously mentioned, it would appear that the occurrence of more than one variety of the species would account for the presence of a substance or substances possessing poisonous properties in the fruit from one particular tree, and its absence in another. At the same time, it is apparent that in the variety bearing poisonous fruit, either the method of treatment to obtain the toxic bodies sometimes destroys the active substance, or, alternatively, changes in chemical composition take place in the fruit during the process of ripening.

## SUMMARY.

1.—An investigation of the fruit (drupe) of the White Cedar (*Melia Azedarach*, L./var. *australasica* C.D.C.; Syn. *M australasica*, A. Juss) growing in New South Wales was carried out to determine its chemical composition and also to isolate the toxic principle.

2.—Proximate analyses of fruits from trees growing at Grafton, and Dubbo respectively, have been made.

3.—Although incomplete, the results of the examination have revealed an idea of the chemical composition of the oil present in the pulp, the presence of a reducing sugar, dextrose, and the characteristics of a resin extracted by ether. A meal consisting largely of starch was also present in the pulp. The kernels of the hard, ribbed seeds contained a fixed oil.

4.—The results of approximately 100 feeding tests on guinea pigs indicated that a toxic principle was present in the fruit of at least one variety of the species, and further, that the toxic substance occurred in the resinous portion extracted with ethyl ether from both ripe and unripe fruit respectively.

5.—A basic substance of alkaloidal nature has been extracted from the resin by means of very dilute sulphuric acid, which substance and the resin from which it was extracted were non-toxic when used in separate feeding tests. *A mixture of both, however, proved toxic.*

6.—The symptoms of poisoning observed following feeding tests on guinea pigs, and the results of *post mortem* examinations, were similar to those obtained with alkaloids of the strychnine type.

## ACKNOWLEDGMENT.

Thanks are due to the following for assistance in obtaining supplies of material:—Forestry Commission of

New South Wales, through the Forest Officers at Dubbo and Grafton respectively; Messrs. Meggitt Ltd., for supplies of fruit from a tree growing in the grounds of their works at Parramatta; and to Mr. Southee, Principal of the Hawkesbury Agricultural College, Richmond, New South Wales.

The Author wishes to express his best thanks to Mr. A. R. Penfold, F.A.C.I., F.C.S., Curator and Economic Chemist, Technological Museum, Sydney, for generous advice and assistance during the progress of the investigation, and also to Mr. E. Cheel, Curator of the National Herbarium, Botanic Gardens, Sydney, for information regarding the botany of the species.

To the Director-General of Public Health, Sydney, thanks are also due for permission to conduct feeding tests at the Department of Public Health, Sydney.

THE CONDENSATION OF  $\alpha\beta$ -DIBROMOCARBOXYLIC ACIDS WITH BENZENE IN THE PRESENCE OF ALUMINIUM HALIDES.

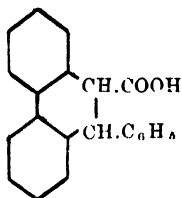
By JOHN CAMPBELL EARL D.Sc., Ph.D.,  
and CLIVE HENRY WILSON.

*(Read before the Royal Society of New South Wales, Oct 7, 1931.)*

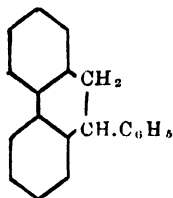
The condensation of trimethylethylene dibromide with benzene in the presence of aluminium bromide yielded  $\alpha\alpha$ -dimethyl- $\beta$ -phenylindene (this Journal 1930, 64, 90), that is, dehydrogenation and ring formation were involved as well as the replacement of the halogen atoms by phenyl groups. It appeared of interest, therefore, to study the behaviour of other dibromo-compounds under similar conditions.

Cinnamic acid dibromide with benzene in the presence of aluminium bromide or ferric chloride gave good yields of  $\alpha\beta\beta$ -triphenyl propionic acid, m.p.  $216.5^\circ$  uncorr., which has been described previously by Kohler and Heritage (American Chemical Journal 1905, 33, 156), and Eijkman (Chemisch Weekblad 1908, 5, 655-666; available in the form of abstract only in J.C.S. abs., 1908, 94, 796.). With aluminium chloride, however, another acid was obtained (m.p.  $148^\circ\text{C}.$ ), and this on examination was found to be a derivative of 9-10-dihydrophenanthrene. Distillation of the calcium salt of the acid yielded a hydrocarbon, the analysis and molecular weight of which indicated the composition  $\text{C}_{20}\text{H}_{16}$ . On oxidation of the hydrocarbon with chromic acid in glacial acetic acid a substance of the composition  $\text{C}_{20}\text{H}_{14}\text{O}$  was obtained, while with aqueous per-

manganate both benzoic acid and phthalic acid were formed. These results are best interpreted by assigning the structures I and II to the acid and the hydrocarbon, respectively.

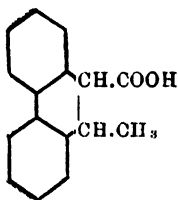


I.



II.

Confirmation of this conclusion was afforded by the application of similar methods to crotonic acid dibromide. In this case, using aluminium bromide,  $\alpha\beta$ -diphenyl butyric acid (m.p.  $188^{\circ}\text{C}.$ ) was produced, while with aluminium chloride a mixture of the same product and another acid (m.p.  $127^{\circ}$ ) was formed. This second acid, on oxidation with chromic acid in the presence of dilute sulphuric acid yielded diphenic acid, and is therefore to be indicated by the structure III.



III

#### EXPERIMENTAL.

**$\alpha\beta\beta$ -triphenyl propionic acid (aluminium bromide as condensing agent).**

Cinnamic acid dibromide (73 grams) was dissolved in benzene (200 cc.), and aluminium bromide (96 grams) dis-

solved in benzene (50 cc.), was gradually added over a period of one and a half hours. There was a vigorous evolution of hydrogen bromide, and after this had moderated the mixture was heated on a boiling water bath for seven hours.

The product was shaken with concentrated hydrochloric acid, when a thick emulsion was formed, together with a lower acid layer. The emulsion was separated as far as possible and heated under a reflux condenser with a ten per cent. solution of sodium hydroxide. A light brown crystalline solid separated, but was re-dissolved on the addition of more water and heating. The acid was precipitated as a light yellow crystalline solid when the alkaline solution was poured into the hydrochloric acid. The crude product (59 grams) was re-crystallised from hot aqueous alcohol when 47 grams of purified acid melting at  $216.5^{\circ}\text{C}$ . (uncorr.) were obtained.

**$\alpha\beta\beta$ -triphenyl propionic acid (ferric chloride as condensing agent).**

Anhydrous ferric chloride (14 grams), cinnamic acid dibromide (20 grams), and benzene (60 cc.), were mixed and the mixture heated on a boiling water bath for six hours. The benzene solution was washed three times with dilute hydrochloric acid and then with water, after which it was shaken twice with a ten per cent. solution of sodium hydroxide (150 cc.). After decolorising with animal charcoal the alkaline solution was acidified when the acid (16 grams) was precipitated. The crude product melted at  $209^{\circ}\text{C}$ . and after twice re-crystallising from aqueous alcohol its melting point was raised to  $215^{\circ}\text{C}$ .

**Ethyl ester of  $\alpha\beta\beta$ -triphenyl propionic acid.**

The calcium salt of the acid (4.5 grams) was suspended in boiling absolute alcohol (40 cc.), and dry hydrochloric

acid gas passed into the boiling solution during three hours. On pouring into water the solid ester (3.6 grams), was precipitated. The crude product melted at  $115^{\circ}\text{C}$ . and, after recrystallisation from alcohol the melting point was raised to a constant value of  $119^{\circ}\text{C}$ . The saponification number of the ester (no. of mgms. of potash required to saponify one gram of the oil) was found to be 170 (calculated for  $\text{C}_{20}\text{H}_{17}\text{COOEt}$ , 170).

**9, 10-dihydro-9-phenyl phenanthrene-10-carboxylic acid.**

Powdered aluminium chloride (60 grams) was added gradually to a solution of cinnamic acid dibromide (90 grams) in benzene (400 cc.). After being allowed to stand overnight, the mixture was heated on a boiling water bath for four hours, at the end of which time the evolution of acid fumes had practically ceased.

The resulting benzene solution was washed twice with concentrated hydrochloric acid and subsequently with water, after which it was extracted twice with a ten per cent. solution of sodium hydroxide (100 cc. each time). On acidifying the alkaline solution a semi-solid material separated, which became hard on standing. After recrystallising from hot aqueous alcohol 76 grams of a product melting at  $145^{\circ}\text{C}$ . were obtained. Further recrystallisation raised the melting point to a constant value of  $148^{\circ}\text{C}$ . (uncorr.).

Equivalent weight by titration with standard alkali; found 299, calculated for  $\text{C}_{20}\text{H}_{15}\text{COOH}$ , 300.

Analysis; found, Carbon 83.9, Hydrogen 5.3 per cent.; calculated for  $\text{C}_{21}\text{H}_{16}\text{O}_2$ , Carbon 84.0, Hydrogen 5.3 per cent.

**The ethyl ester of the above acid.**

The ethyl ester was prepared by a similar method to that employed in the case of  $\alpha\beta\beta$ -triphenyl-propionic acid. The



recrystallised product melted at  $116^{\circ}\text{C}.$ , but a mixed melting point with ethyl-triphenyl-propionate (m.p. $119^{\circ}\text{C}.$ ) showed a depression to  $79^{\circ}\text{C}.$  Saponification value, found 172, calculated for  $\text{C}_{20}\text{H}_{15}\text{COOEt}$ , 171.

#### 9-phenyl, 9, 10-dihydrophenanthrene.

The acid (10 grams) from the aluminium chloride condensation was finely powdered and mixed with an excess of soda lime. The mixture was heated in a copper retort until no further product distilled over. The distillate was transferred to a filter and washed first with dilute sodium carbonate solution and then several times with water. The resulting product (1.4 grams) after recrystallisation from alcohol melted at  $121.5^{\circ}\text{C}.$

Found, Carbon 93.7, Hydrogen 6.3; calculated for  $\text{C}_{20}\text{H}_{16}$ , Carbon 93.7, Hydrogen 6.3 per cent.

Molecular weight, found (by Mr. R. A. Wallace), 259; calculated 256.

#### Oxidation of the Hydrocarbon.

(a) With chromic acid in glacial acetic acid.

The hydrocarbon (1.9 grams) was dissolved in glacial acetic acid (25 cc.) and chromic acid (10 grams) gradually added. The solution was boiled under a reflux condenser for 10 minutes, after which it was poured into water. The separated oil was extracted with benzene, and the benzene solution shaken with a 10 per cent. solution of caustic soda. The washed and dried benzene solution, after evaporation, yielded an oil which crystallised on standing. The crude product (1.1 grams) melted at  $103^{\circ}\text{C}.$ , and on recrystallisation from ligroin the melting point was raised to a constant value of  $105\text{--}106^{\circ}\text{C}.$

Found, Carbon, 88.3, Hydrogen 5.2 per cent.; calculated for  $\text{C}_{20}\text{H}_{14}\text{O}$ , Carbon 88.8, Hydrogen 5.2 per cent.

(b) With potassium permanganate.

The hydrocarbon (2 grams) was mixed with a solution of potassium permanganate (2 grams) in water (400 cc.), and the mixture was boiled under a reflux condenser until all the permanganate had been reduced. The solution was filtered and again boiled with two successive quantities of 2 grams of potassium permanganate, the last portion being not completely reduced. The excess of permanganate was destroyed with sodium bisulphite, and the solution acidified and extracted with ether. From the ethereal extract 0.4 grams of benzoic acid were isolated. The aqueous solution was neutralised and evaporated to small bulk and again acidified, when 0.42 grams of a solid material, identified as phthalic acid, were obtained.

**$\alpha\beta$ -Diphenylbutyric acid.**

$\alpha\beta$ -Dibromobutyric acid (4 grams) was dissolved in benzene (150 cc.), and aluminium bromide (7 grams) added. The mixture was heated on a boiling water bath for six hours, after which it was washed twice with concentrated hydrochloric acid and subsequently with water. The benzene solution was then shaken with two successive quantities (50 cc.) of 10 per cent. caustic soda solution, from which the acid (3.1 grams) was precipitated by the addition of hydrochloric acid. On recrystallisation from aqueous alcohol, 2.7 grams of the pure acid, melting at  $187^{\circ}\text{C}.$ , were obtained. Equivalent by titration, found 237.5, calculated for  $\text{C}_{15}\text{H}_{15}\text{COOH}$ , 240.

**9, 10-dihydro-9-methyl phenanthrene-10-carboxylic acid.**

$\alpha\beta$ -Dibromobutyric acid (15 grams) was dissolved in benzene (250 cc.) and aluminium chloride (20 grams) added. After heating on a boiling water bath, the product was treated as in the previous experiment, 10.5 grams of a crude acid material being obtained. This was separa-

ted into two fractions by crystallisation from alcohol, the less soluble portion (2.1 grams) being identified as  $\alpha\beta$ -diphenylbutyric acid (mpt.  $188^{\circ}\text{C}.$ ). The more soluble portion (4.5 grams), on repeated crystallisation, attained a constant melting point of  $127^{\circ}\text{C}.$

Found, Carbon 80.6, Hydrogen 5.8 per cent.; calculated for  $\text{C}_{16}\text{H}_{14}\text{O}_2$ , Carbon 80.6, Hydrogen 5.9 per cent

Equivalent, found, 235; calculated for  $\text{C}_{15}\text{H}_{11}\text{COOH}$ , 238.

#### Oxidation of the above acid.

The acid (2 grams) was mixed with water (300 cc.) and sulphuric acid (15 cc., concentrated), and to the mixture chromic acid (25 grams) was added, the whole being boiled under a reflux condenser for 4 hours. After standing overnight, the insoluble material was filtered off and treated with ammonia. The ammoniacal solution was filtered and acidified with hydrochloric acid, when a white precipitate (1.78 grams) separated. The crude material melted at  $221^{\circ}\text{C}.$ ; after two recrystallisations from water, the purified product melted at  $227^{\circ}\text{C}.$ , and showed no depression of melting point when mixed with an authentic sample of diphenic acid.

The authors' thanks are due to Mr. S. L. Leach, B.Sc., for assistance in the experimental work described in this paper.

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THE ESSENTIAL OIL OF *LEPTOSPERMUM LIVERSIDGEI*, VARIETY B., AND THE OCCURRENCE OF ISOPULEGOL.

PART I.

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(Read before the Royal Society of New South Wales, Nov. 4, 1931.)

In a paper entitled "Observations respecting some essential oils from *Leptospermum Liversidgei*," published in the Journal and Proceedings of the Royal Society of New South Wales, Volume LVI (1922), pages 80-87, the author directed attention to the probable occurrence of several forms of *Leptospermum Liversidgei* as evidenced by the composition of the essential oils. Field observations conducted since that date have confirmed the views then expressed. Numerous distillations of essential oils from the leaves and terminal branchlets collected from various parts of Queensland and New South Wales supported by field investigations have shown a similar occurrence of physiologic forms to that reported in the case of *Eucalyptus dives*. (See this Journal, Vol. LXI (1927), pages 54-67.) The oil obtained from Variety B. was found to contain citronellal in quantity (no citral) and thus differed considerably from the Type which contained the aldehyde citral instead.

The aldehyde content was determined by the bisulphite method, and for the reasons set forth in the paper entitled "The Estimation of Citronellal and Citral in Australian Essential Oils," published in the Journal and Proceedings

of the Sydney Technical College Chemical Society, Volume 4, pages 53-60, it was found necessary to redetermine the citronellal content by more reliable and accurate methods. The re-examination by these new methods, and particularly the Holtappel method, as modified by Penfold and Arne-  
man (l.c.), shows the actual aldehyde content to be from 33-42%, as per results shown in Table "A." It was apparent, therefore, that the difference in the results obtained between the modified Holtappel method and the bisulphite method was due to the presence of an unidentified substance, most probably a closely related alcohol which was absorbed in the bisulphite liquor and estimated as aldehyde, as mentioned on page 55 of aforementioned publication. A careful examination revealed the presence of isopulegol, which according to J. L. Simonsen ("The Terpenes," volume 1, page 254) has not been found to occur in nature. Although citronellal is readily converted into isopulegol, yet the evidence adduced in this investigation proves beyond all doubt the natural occurrence of this alcohol in the freshly distilled oils. The isolation and identification of isopulegol, both free and combined, in this particular oil is the first authentic record of its natural occurrence.

There still appears to be a further unidentified constituent, as the quantity of isopulegol isolated, together with the citronellal as determined, plus the sesquiterpene alcohol, falls considerably short of the total amount of acetylisable constituents. This body is now being sought and the results of the further investigation of this oil will be made available at a later date.

#### **Essential Oils.**

The essential oils were of a pale yellow to brown colour, moderately mobile, with a pronounced odour of citronellal. Nearly 2,000 lbs. weight of the leaves and terminal branch-

lets, cut as for commercial purposes, on subjection to steam distillation, gave an average yield of 0.5% of oil. The identity of *d*- $\alpha$ -pinene and citronellal, as previously reported, were confirmed, whilst the occurrence of isopulegol, together with a sesquiterpene alcohol and their caprylic and caproic acid esters has now been established.

### EXPERIMENTAL.

The leaves and terminal branchlets of Variety B., cut in all instances as for commercial distillation, and obtained principally from the Coraki District of New South Wales, yielded, on distillation with steam, crude oils possessing the chemical and physical characters as shown in accompanying Table "A."

Every consignment was separately examined, but for the purposes of this communication the results for the last consignment only are recorded.

300 c.c. of crude oil, 30/6/'31, were distilled at 10 mm. with the following results, viz.:—

No.	Boiling Point	Volume	$d_{15}^{15^{\circ}}$	$\alpha_D^{20^{\circ}}$	$n_D^{20^{\circ}}$	Aldehyde Content
1	48-55'	17 c.c.	0.8622	+ 37.3°	1.4654	13%
2	56-80'	16 c.c.	0.8689	+ 23.0°	1.4611	37%
3	80-95"	196 c.c.	0.8813	+ 9.3°	1.4604	53%
						Ester No.
4	95° (10 mm.)-115° (5 mm.)	15 c.c.	0.9151	+ 8.75°	1.4763	82
5	115° (5 mm.)-130' (5 mm.)	14 c.c.	0.9509	+ 8.75°	1.4875	52

### Determination of *d*- $\alpha$ -pinene.

The presence of pinene in the first and second fractions was determined in the first communication referred to by the preparation of the nitrosochloride. It was deemed advisable to confirm the presence of this terpene in Fraction No. 1 by removing small quantities of the aldehyde with sodium bisulphite solution. The treated oil was then washed with water, dried and distilled over metallic sodium at 764 mm. The major portion of the

oil distilled at 154-156° (764 mm.) and had  $d_{15}^{15^\circ}$  0.8621  $a_D^{20^\circ} + 40^\circ$   $n_D^{20^\circ}$  1.4646. Oxidation with potassium permanganate resulted in an excellent yield of pinonic acid, which after purification from petroleum ether (boiling point 50-60°) melted at 70°.

0.5170 gram in 10 c.c. chloroform gave a polarimeter reading of +4.6°,  $[\alpha]_D^{20^\circ} = +89$ .

#### *Determination of citronellal.*

The amount of citronellal in fraction No. 3 was found to be 53%. A sample of the aldehyde purified through the bisulphite compound gave the following chemical and physical constants, viz.:—

Boiling point 88-91° (10 mm.)  $d_{15}^{15^\circ}$  0.8611  $a_D^{20^\circ} + 10.1$   
1.4484.

The semicarbazone prepared therefrom melted at 82.5°.

#### *Determination of isopulegol.*

50 c.c. of fraction 3 were heated with an equal weight of phthalic anhydride in benzene solution for eight hours on a boiling water bath. (Only a small quantity of isopulegol is produced from pure citronellal under similar conditions.) The phthalic acid ester prepared therefrom was treated with excess of 25% sodium hydroxide solution and the liberated alcohol blown over with steam. The water-white distillate possessed the characteristic odour of isopulegol, which resembles very closely that of menthol. On distillation it boiled at 92-94° (10 mm.) and had  $d_{15}^{15^\circ}$  0.9199  $a_D^{20^\circ} - 1.75^\circ$   $n_D^{20^\circ}$  1.4702. Many samples of this alcohol were prepared from the various consignments of oils and gave the following range of constants, viz.:—

Boiling point 92-94° (10 mm.)  $d_{15}^{15^\circ}$  0.9162-0.9189  $a_D^{20^\circ}$   
-1.1° to -6.1°  $n_D^{20^\circ}$  1.4702-1.4730.

It is of interest to record that samples of isopulegol prepared from the crude oil immediately after distillation were found to have a much higher specific gravity than when prepared through fraction No. 3 distilling between 80-95 (10 mm.). The chemical and physical characters of such preparations were as follows, viz.:—

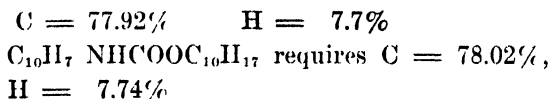
Boiling point 93-94°  $d_{15}^{15}$  0.9221-0.9228  $\alpha_D^{20}$  -1.3° to -5.6°  $n_D^{20}$  1.4716-1.4728.

In the absence of definite evidence it is assumed that the higher specific gravity is due to contamination with small quantities of other alcoholic bodies, most probably darwinol. The evidence in support of this statement was obtained when small quantities of alcohols isolated from the higher boiling fractions were examined. These were found to contain isopulegol, together with an unidentified alcohol which had a rose-like odour. In view of the high specific gravity it can only be attributed to darwinol and not to geraniol or citronellol.

The identity of the alcohol with isopulegol was obtained by the preparation of various derivatives. On treatment with cyanic acid a good yield of allophanate was obtained of melting point 219°-220°. Simonsen in "The Terpenes," volume 1, states that this alcohol can be characterised by this derivative. The writer, however, has found that the naphthylurethane is very characteristic. On allowing equimolecular proportions of isopulegol and naphthylisocyanate to remain in contact at room temperature combination resulted in less than twelve hours. This excellent derivative on purification from methyl alcohol melted at 112-113°.

0.1 gram on combustion gave 0.2857 gram CO<sub>2</sub> and 0.0693 H<sub>2</sub>O.





Many combustion determinations made on the purified alcohol during the past two years gave unsatisfactory results, the carbon estimations being always low. The results, therefore, are not recorded.

The identity of the alcohol with Isopulegol was confirmed beyond all doubt by its oxidation to isopulegone.

16 c.c. of the alcohol having  $d_{15}^{15^\circ}$  0.9189  $\alpha_D^{20^\circ}$   $-1.1^\circ$   $n_D^{20^\circ}$  1.4724 were treated with 160 c.c. of Beckmann's chromic acid mixture at room temperature when 10 c.c. of a ketone possessing the following chemical and physical characters was isolated, viz. :—

Boiling point  $96-98^\circ$  (10 mm.)  $d_{15}^{15^\circ}$  0.9623  $\alpha_D^{20^\circ}$   $-4.45^\circ$   $n_D^{20^\circ}$  1.4691.

The following derivatives of the ketone were obtained, viz. :—

1. (a) A semicarbazone of melting point  $173^\circ$  with a specific rotation in chloroform solution of  $-29.41^\circ$  ( $20^\circ$ ).
- (b) A semicarbazone of melting point  $147-148^\circ$  with a specific rotation of  $+36.5$  ( $20^\circ$ ).
2. (a) An oxime of melting point  $133-134^\circ$ , optically inactive in chloroform solution.
- (b) An oxime of melting point  $124^\circ$  with a specific rotation in chloroform solution of  $+14.9^\circ$  ( $20^\circ$ ).

It is worthy of note that the best yields and quality of isopulegol were obtained when the phthalic acid ester was

prepared by prolonged treatment in benzene solution on the boiling water bath. Heating in an oil bath at  $140^{\circ}$  for four hours resulted in a considerably diminished yield of alcohol.

*Determination of the esters present in fractions 4 and 5.*

These fractions were saponified with normal alcoholic potassium hydroxide solution at room temperature. In this way 7 c.c. of liquid acids were obtained which behaved as follows on distillation, viz:—

1st drops  $245^{\circ}$  at 768 mm.

Between  $245-252^{\circ}$  2 c.c.

Between  $253-270^{\circ}$   $3\frac{1}{2}$  c.c.

On account of the comparatively small quantities and the slight decomposition it was decided to convert portion of them to their silver salts.

0.4650 gram silver salt of the first fraction gave on ignition 0.1846 gram Ag. Ag. = 40.47%.

0.4709 gram of silver salt of second fraction similarly treated gave 0.2885 Ag. Ag. = 38.94%.

These results point to the acid consisting principally of caprylic acid, the silver salt of which would yield on ignition 38.71% Ag.

A small amount of silver salt prepared from the aqueous acid gave the following results on examination, viz:—

0.0620 gram on ignition gave 0.0279 gram Ag.

Ag. = 45%.

The silver salt of caproic acid on ignition would yield 48.43% Ag.

Computing from these results and taking into account the boiling point range of the mixed liquid acids, the writer is of the opinion, on the evidence available, that they con-

sist of a mixture of caprylic and caproic acids, the former predominating.

The residual oil after saponification was treated with phthalic anhydride in benzene solution for a prolonged period, but only a very small quantity of alcohol was regenerated from the phthalic acid ester produced. Two preparations resulted as follows, viz.:—

$$(a) \quad d_{15}^{15^{\circ}} 0.9028 \quad \alpha_D^{20^{\circ}} \pm 0^{\circ} \quad n_D^{20^{\circ}} 1.4668 \text{ (4 c.c.)}$$

$$(b) \quad d_{15}^{15^{\circ}} 0.9253 \quad \alpha_D^{20^{\circ}} \pm 0^{\circ} \quad n_D^{20^{\circ}} 1.4690 \text{ (2 c.c.)}$$

Both were found to consist of a mixture of isopulegol with an unidentified alcohol which, on account of its high specific gravity and odour, appears most likely to be darwinol.

The remainder of the oil, after treatment with phthalic anhydride, gave 16 cc. distilling between  $140^{\circ}$  and  $170^{\circ}$  at 20 mm. It had  $d_{15}^{15^{\circ}} 0.9477$   $\alpha_D^{20^{\circ}} + 5.5^{\circ}$   $n_D^{20^{\circ}} 1.4902$ , and was found to consist essentially of an unidentified sesquiterpene alcohol accompanied by small quantities of sesquiterpene.

#### *Determination of alkali soluble bodies.*

The crude oils, on treatment with 8% sodium hydroxide solution yielded under 1% of alkali soluble bodies. The quantities isolated were too small for definite identification, but from their general physical characters and deportment appeared to be a mixture of eugenol with citronellie acid.

My thanks are due to Mr. F. R. Morrison, F.C.S., A.A.C.I., Assistant Economic Chemist, for much assistance in this investigation, and to Mr. P. T. Aubin, District Forester at Coraki, New South Wales, for his help in procuring the various supplies of plant material.

Essential Oils from leaves of *LEPTOSPERMUM LIVERSIDGEI*—Variety "B"

Date	Source of Material.	Weight of Leaves.	Yield of Oil.	$d_{15}^{15}$	$\alpha_D^{20}$	$n_D^{20}$	Solubility in 70% Alcohol (by weight)	Ester No 14 hours hot sap	Ester No after Acetylation	Aldehyde Content	Method of Aldehyde determination
26/9/1922	Stradbroke Island, Q.	78 lbs.	0.64%	0.8831	+9.4°	1.4609	1.6 vols	—	—	75%	Bisulphite method
15/10/1926	Woodburn, N.S.W.	193 lbs.	0.62%	0.8985	+9.5°	1.4665	1.2	44.0	260	31%	Oximation
11/4/1929	Bonalbo, N.S.W.	173 lbs.	0.46%	0.8900	+13.4°	1.4665	1.6	43.0	244	33% 26%	Modified Holtappel Oximation
18/9/1929	do.	1154 lbs.	0.41%	0.8960	+11.25°	1.4682	1.4	—	—	38%	Modified Holtappel
30 6/1931	do.	394 lbs	0.4%	0.8936	+11 7°	1.4662	1.4	47	255.3	41.4%	do. do.

NOTES ON THE PERICALYMMAE SECTION OF  
THE GENUS *LEPTOSPERMUM* (WITH DESCRIPTIONS  
OF THREE NEW SPECIES).

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(Read before the Royal Society of New South Wales, Nov. 4, 1931.)

In the Journal and Proceedings of this Society (1918-1923) I have already submitted for consideration descriptions and notes on six species and one variety of the genus *Leptospermum*. In the present paper I propose to give a brief outline history of the genus and the sections which have been raised to generic rank by certain authorities, more particularly in connection with the Section Pericalymma, the species of which seem to be much more widespread over Australia than has hitherto been recorded.

The genus *Leptospermum* was originally established by the Forsters (1776), who published a description and gave details of certain characters of seven species of Myrtaceous plants, together with text-figures of four of these, including *Leptospermum scoparium*, native of New Zealand, commonly known as "Manuka" or "Tea-tree," which is generally regarded as the type of genus. Four of the species enumerated in the above work have since been transferred to *Metrosideros*, one to *Melaleuca*, and the other to *Baeckea*. It is interesting to note that one of the Forsters, in a subsequent work (Geo. Forster, 1786), transferred the species of *Leptospermum scoparium* to *Melaleuca*, and he was followed by Wendland (1819), but

so far as I can ascertain, no valid reasons were given for this change. Robert Brown (1831) seems to have had a very clear conception of the plants allied to the type species of what is commonly accepted as *Leptospermum*, for we find that he made the following statement:—“*Leptospermum*, of which nearly thirty Australian species have been observed, exists also in New Zealand and in the Moluccas. In Terra Australis its maximum is decidedly in the principal parallel, and, like *Melaleuca*, it is much more abundant in the southern region than within the tropics.”

DeCandolle (1828) enumerated twenty-six species of *Leptospermum*, including three which he classed under a section as *Agonis*. Don (1832) did not take up the name *Agonis*, but enumerated the three species of DeCandolle's section *Agonis* under *Billotia*. The names *Billotia* of Don and *Billottia* of R. Brown (1832) were not taken up by Bentham and other workers, probably on account of a Rubiaceous plant being recorded by Colla (1825) as *Billiota*. Bentham (1866) established the sectional name *Agonis* of DeCandolle as a genus, and set up two sections, viz.: *Taxandria*, with 10 stamens regularly opposite the calyx-lobes and petals, ovules 2 in each cell; and *Ataxandria*, with 20 to 30 stamens, non-opposite the centre of the petals, ovules 4 to 6 in each cell. Ten species are enumerated under the genus *Agonis* by Bentham (l.c.), all of which are from Western Australia, and are easily recognised by the flowers being densely packed in globular heads, besides the other characters referred to above.

Bentham (1866) enumerated 20 species and 15 varieties, which were classed under three sections, based chiefly on the number of cells and the shape and size of the seeds

contained in the capsules, which may be characterised as follows:—

*Fabricia*—Capsules 6 to 10 celled. Seeds few, the fertile ones comparatively broad and acutely angular, or more or less winged.

*Euleptospermum*—Capsules usually 5-celled or rarely reduced to 4 or 3 cells. Seeds all narrow-linear, the fertile seeds scarcely distinguishable from the infertile seeds.

*Pericalymma*—Capsules 3-celled, or very rarely 4-celled. Ovules 4 to 8 in each cell, the fertile seeds more or less cuneate and usually twice the size of the infertile ones.

In a subsequent work, when commenting on these characters, Bentham (1869, p. 135) remarked that he “regarded the differences in the structure or shape of the seeds as a sectional rather than a generic character.”

Bentham also regarded the characters of the numerous species of *Leptospermum* as exceedingly vague and variable, and stated that “they appear all to be connected by an almost infinite series of intermediate gradations.” Bentham further remarked (l.c.) “that he found the genus in a singular state of confusion. In the first place it long formed a common receptacle for all capsular Myrtaceae with small coriaceous leaves and numerous short stamens. Again, a few common species, scarcely distinguishable by any positive characters, are yet so polymorphous, especially in our gardens, as to have been enormously multiplied by horticultural botanists, whilst almost all those which showed any tangible specific differences have been at various times proposed as distinct genera. And, lastly, notwithstanding the facility of examining living material of several species common in our plant houses, errors in

some of the important characters originally misunderstood have been servilely copied by almost all modern botanists.”

The three sections as defined by Bentham (1866) form natural, easily recognised groups, especially if the mature seeds be taken into account. Although the section *Pericalymma* was established by Endlicher (1837), based chiefly on the 3-celled ovary and a reduced number of ovules in each cell, Schauer (1844-45) seemed to regard this of sufficient importance to raise the sectional name to generic rank, but Baillon (1880) and Nidenzu (1893) followed, in the main, Bentham's classification.

It is interesting to note that, in a general review of the characters of certain *Leptospermoideae*, Bentham (1869) observed that the characters of *Pericalymma* also occurred in two species of *Euleptospermae* with numerous ovules (i.e., *L. abnorme* and *L. Roci*). It is chiefly owing to the extreme variation of the forms of leaf, the degree of pubescence and the variable number of cells in the ovaries that so much confusion has been created in the nomenclature of this genus. This, no doubt, has arisen owing to the small number or fragmentary nature of the specimens upon which some of the species, as well as genera, were founded, and probably also because of the difficulty of specific determination due to the original description being inadequate as well as to the literature being scattered.

In this regard, we may review *Leptospermum abnorme* F.v.M. Herb. of Bentham. The specimens on which this species was founded were collected by Dr. Herman Beckler on the Hastings River in New South Wales, and originally described by Mueller (1860) under the name *Kunzea brachyandra*. It appears, however, that Mueller afterwards changed the name in the herbarium to *Leptospermum abnorme*, which was adopted by Bentham (1866),



who records *A. Cunningham* and *J. Dallachy* having also collected specimens of the species from the same locality. In addition to the Hastings River specimens, *Bentham* (l.c.) also records the species from Severn River, N.S.W., collected by C. Stuart; Northumberland Island (R. Brown) and Duck Creek, Queensland (*J. Dallachy*), and Port Essington, North Australia (*Armstrong*). In the National Herbarium, Sydney, there are specimens from the Endeavour River (collector?) ex herbarium, Brisbane, which in no way differ from the Hastings River and Port Essington specimens. There are also specimens from the Finis River, Northern Territory, collected by W. S. Campbell, who states that "it looks like *Agonis*, and is locally known as 'Weeping Tea Tree.' " The Finis River specimens have rather long leaves, more or less covered with a silky down of a silver colour, but are narrower than the Port Essington and Endeavour River specimens. *White* and *Francis* (1920) have transferred the Endeavour River specimens to *Agonis* as a new species under the name *A. longifolia*.

The chief characters on which they have founded the species are the longer leaves and puberulent calyx-tube. Having examined a very large series of specimens, collected over a very wide area of the northern parts of New South Wales, viz., Wauchope, Port Macquarie, Woodford Island, Copmanhurst, Wilson's Downfall, Grafton to Dalmorton, Casino, Tooloom River, Tenterfield and Ballina, as well as a series of specimens from the following localities in Queensland—Silverwood and Crow's Nest, Darling Downs, Stradbroke Island, Blunder Creek, Freshwater Creek, Redcliffe and Maryborough, I am unable to draw any sharp line of distinction between the original *Kunzea brachyandra* of *Mueller* (which includes *Leptospermum abnorme* F.v.M. Herb. of *Bentham*) and the *Agonis*

*abnormis* and *Agonis longifolia* of White and Francis. The plants belonging to the above species, together with those of *Agonis elliptica* White and Francis, and *Agonis elliptica* var. *angustifolia* White and Francis (1920), have the characteristic 3-valved capsules and more or less cuneate or oblong fertile seeds intermixed with narrower infertile ones, as is seen in the section Pericalymma.

In view of this, I suggest that these plants be classed as follows:—

*Leptospermum* (Sect. Pericalymma) *brachyandrum* nov. comb. (*Leptospermum abnorme* F.v.M. Herb. Benth.) (*Agonis abnormis* and *A. longifolia* White and Francis).

*Leptospermum* (Sect. Pericalymma) *Whitei*, nov. comb. (*Agonis elliptica* White and Francis). The specific name *elliptica* is already preoccupied for a species of *Leptospermum*, hence it is proposed to dedicate this rather distinctive series of plants to Mr. Cyril Tenison White, Government Botanist of Queensland, who has done so much towards the investigation of the flora of Queensland.

The Rev. B. Scortechini (1881-2), in commenting on some plants collected at Stradbroke Island, which he listed under *Leptospermum abnorme*, F.v.M. Herb., stated that "it is with some hesitation that I introduce this plant into the South Queensland flora. Its characters do not altogether answer the description of the typical *L. abnorme*."

I have not seen the specimens referred to by Scortechini, but suggest that they may belong to the proposed new combination, *Leptospermum Whitei* Cheel (*Agonis elliptica* (White and Francis) or the var. *angustifolia* of the latter, which show several transitory forms between

*L. brachyandrum* (F.v.M.) Cheel, and *Agonis Scortechiniana* F.v.M., which incidentally is referred to by Woolls (1889), who says that "it is described by Baron von Mueller as being a remarkable species, extending the limits of the genus (*Agonis*) to the eastern coast."

With regard to *Agonis Scortechiniana*, it would appear at first sight to be correctly classed in its proper genus, but when carefully examined it will be noted that the flowers are not closely packed in dense globular heads, as in the whole of the species of the genus, as found in Western Australia, but rather in axillary clusters or terminal corymbose-racemes.

The individual flowers of *Agonis Scortechiniana*, as well as those of the closely allied species *Leptospermum Whitei* (*Agonis elliptica* and var. *angustifolia*), are not strictly sessile, but are shortly pedicellate, and although in the early stage of development are crowded together in the numerous brown, scarious, or more or less woolly bracts, when fully developed are seen to be in more or less loose fascicles of 2 to 5 flowered cymes. Plants of several other species of the genus *Leptospermum* have the flowers arranged in clusters or fascicles. The most noteworthy of these are *L. stellatum*, *L. attenuatum* and *L. podanthum*. In this group, however, the pedicels are much more elongated. The capsules and seed characters of the two groups, viz., those with the flowers arranged in clusters with very short pedicels, and those with the flowers arranged in clusters with elongated pedicels, are very much the same and will form the subject of a separate paper which is now being prepared for the purpose of linking up several other species, including *Leptospermopsis* s. le Moore (1920), with the Section Pericalymma.

## LEPTOSPERMUM TRIVALVUM, sp. nov.

Frutex gracilis, 1-3 m. altus, ramis plus minusve pilosis, viliis aliquantum fascicularibus, acutis, 3 aut interdum 5 nervatis, ad 4-7 mm. longis, 1.5-2.5 mm. latis, foliis junioribus aliquantum argenteo-tomentosis, glabrecentibus; floribus albis axillaribus solitariis, tubo calycis 3-4 mm. lato, ad basim vix attenuato, sericeo-tomentoso, lobis 1-2 mm. longis, glabris sed glandulis punctatis, petalis suborbicularibus, ovario pubescente, 3 loculari, stylo 1.5-2 mm. longo, stigma minute capitata; fructibus 3-3.5 mm. latis valvis tubum vix excedentibus; seminibus fertilibus paucis plus minus ve cuneatis.

Slender shrub, varying from 3 to 8 feet high, branches and twigs more or less covered with silky hairs. Leaves somewhat clustered, lanceolate and slightly convolute at the apex, acute, 3-veined or occasionally 5 prominent veins, the larger leaves 4 to 7 mm. long, 1.5 to 2.5 mm. broad, the others in each cluster smaller, somewhat silvery-tomentose when young, becoming glabrous with age. Flowers white, singly in each cluster of leaves or axillary when the leaves are not clustered. Calyx-tube 3-4 mm. diameter, slightly tapering at the base, silky-hairy, the lobes 1 to 2 mm. long, glabrous, but dotted with oil-glands. Petals sub-orbicular, twice as large as the sepals, or in luxuriant plants larger. Ovary pubescent, 3-4 celled. Style 1.5 to 2 mm. long. Stigma minutely capitate. Fruits about 3 to 3.5 mm. diameter, the valves slightly exceeding the calyx-tube. Fertile seeds few, comparatively large, more or less well shaped, intermixed with smaller, narrower, infertile ones.

This is an interesting species, usually found on sandy or quartzite mountains or ridges in the southern and western parts of the State of New South Wales. It has somewhat the appearance of *L. arachnoideum* in the herbarium, but in the field it has quite a different habit, being more upright, and the leaves are broader and more silvery.

It has previously been confused with *L. arachnoideum*, *L. myrtifolium*, *L. myrsinoides* and *L. attenuatum*, but is abundantly distinct, being constantly 3-celled, whereas all the others are normally 5-celled (except *L. myrsinoides*, which varies from 4 to 5), and the seeds place it in the Pericalymma Section, whereas the fertile and infertile seeds of *L. arachnoideum*, with which it has mostly been compared, are all narrow and slender, characteristic of the Euleptospermeae.

Dubbo to Tomingley, J. H. Maiden, September, 1898, and E. Cheel, October, 1930. Type. Other localities are: Dubbo to Gilgandra (W. Forsythe, October, 1901); Wyalong (J. L. Boorman, September, 1918); Wyalong (R. H. Cabbage, No. 113, September, 1900); Gilgandra (G. A. Withers, November, 1925); Bogan Gate (K. Walker, June, 1908; E. H. Ising, No. 2171); Warrumbungle Ranges (W. Forsythe); Ardlethan (R. H. Cabbage, No. 4212); Harvey Ranges, Peak Hill (J. L. Boorman); Nymagee (R. H. Cabbage, 4464); Barellan (W. Bourke); Cobar (Archdeacon Haviland); Hill End (R. H. Cabbage, No. 2768); Fifield (R. H. Cabbage, No. 1949); Lachlan River (J. Duff, 1882); Ilford to Rylstone (E. Cheel); Orange and Parkes (Dr. McGillivray, per A. Morris, No. 1117); Yass (Rev. J. W. Dwyer); Bowan Park, near Cudal (W. F. Blakely); Yalgoblin (J. L. Boorman); Bumberry (Dr. J. B. Cleland); Queanbeyan (R. H. Cabbage, No. 3370); Gilmore to Tumut (J. L. Boorman). A specimen from Black Mountain, west of Queanbeyan (R. H. Cabbage, No. 3091) has fruits tapering at the base into slender pedicels, which are perfectly glabrous, and may not belong to this species. There are also specimens from Mitta Mitta River, Victoria (ex Williamson's Herb. No. 1657) collected by S. Clinton.

## LEPTOSPERMUM SEMIBACCATUM, sp. nov.

Frutex virgatus, 1-2 m. altus, foliis juvenilibus virgisque sericeo-hirsutus, glabrescentibus, foliis adultis plus minusve glabris, planis, ellipticis vel oblongo-lanceolatis, 6-14 mm. longis, 3 mm. latis, 3-5 nervatis, bracteis imbricatis fuscis marginibus fimbriatis flores circumdatis, calycis tubo minute hirsuto, glabrescente, primo plus minusve succulento deinde aliquantum sicco et rugoso, sepalis 1.5 mm. longis acutis, ovario 5-loculari ovulis paucibus, capsularibus sessilibus 3-4 mm. latis, valvis tubum vix excedentibus.

Shrub with several whip-stick-like stems springing from the base, usually 1-2 M. (4 to 5 feet) high or rarely more than 2 M. (7 feet). Bark more or less fibrous. Juvenile leaves and twigs silky-hairy, but disappearing with age, so that the fully-developed leaves are almost glabrous. Leaves plain, elliptical to oblong-lanceolate, 6-14 mm. ( $\frac{1}{4}$  to  $\frac{1}{2}$  inch) long, 3 mm. ( $\frac{1}{8}$  inch) wide, 3 to 5 nerved. Flowers enclosed, with brownish-coloured imbricate bracts with fimbriate margins. Calyx-tube minutely silky-hairy, but almost glabrous with age, at first somewhat softly-succulent and berry-like, drying up and much wrinkled with age. Sepals 1.5 mm. ( $\frac{1}{16}$  inch) long, acute. Ovary 5-celled, with few ovules. Capsules sessile, 3-4 mm. ( $\frac{3}{16}$  inch) diameter, the valves very slightly exceeding, or more often level with, the rim of the calyx-tube.

An interesting plant with fruits more or less succulent and somewhat resembling those of *L. glaucescens* Schauer, which is united with *L. lanigerum* by Bentham and others as a synonym, but which is abundantly distinct from that species, as I will endeavour to show when dealing with the *lanigera* series.

The original specimens of this species were collected on Wallis Island, Tuncurry, in May, 1925. The plants were in the fruiting stage, with a few flowers in the early bud stage, but no fully-developed flowers were present. Speci-

mens have since been collected by Mr. C. T. White on Moreton Island, Moreton Bay, in Queensland, also in the fruiting stage, so that I am unable at present to describe the petals, stamens and style.

LEPTOSPERMUM SPIAEROCARPUM, sp. nov.

Frutex virgatus, 1-2.5 m. altus, foliis 6-10 mm. longis, 2-5 mm. latis, lanceolatis acutis, juvenilibus aliquantum hirsutis glabrescentibus, obscure 3-nervatis, floribus solitariis terminalibus bracteis scariosis fuscis circumdatis, tubo calycis leviter hirsutis, lobis acutis plus minusve sericeo-hirsutis vel tomentosis, petalis orbicularibus albis, circiter 5 mm. latis, staminibus 25-30, capsulis maturis plus minusve sphaericis, 3-vel nonnunquam 4-locularibus, valvis sphaerico-convexis, seminibus linearibus circiter 5 mm. longis.

Shrub, with upright, slender, loose branches, from 4 to 8 feet high. Leaves 6 to 10 mm. long, 2 to 5 mm. broad, lanceolate, acute, slightly hairy in the juvenile stage, glabrous with age; venation not prominent but obscurely 3-nerved; oil glands more or less porose-punctate. Flowers singly terminal on the young branchlets, surrounded with several scarious brownish-coloured bracts. Calyx-tube slightly hairy, lobes acute, more or less covered with short silky hairs or down. Petals orbicular, white, about 5 mm. diameter. Stamens 25 to 30, almost as long as the petals. Style short, with a capitate stigma. Capsule somewhat turbinate, but when fully matured spherical, normally 3-celled, but occasionally 4-celled, the valves much domed before finally opening to shed the seeds, which, both fertile and infertile, are linear and about 5 mm. long.

An exceedingly interesting plant, flowering during October, the leaf characters somewhat resembling those of *L. nitidum* of Hooker, which is confined to Tasmania, but easily separated from that species, which has smaller fruits, always 5-celled. It has also some resemblance to *L. lanigerum* var. *macrocarpum* Maiden and Betcher, but this

latter has exceptionally large fruits, also constantly 5-celled. *L. sphaerocarpum* was originally collected at Caboon, 7 miles north of Rylstone, by Mr. R. T. Baker in October, 1893. It has since been collected in the same neighbourhood by E. Cheel, and at Cox's Creek, near Rylstone, by W. Dunn. Also at Capertee, Rocky Glen, Coonabarabran, Warrumbungle Ranges, Clarence Siding, Hartley Vale, Mount Wilson, Mount Victoria, and Blackheath.

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## NOTES ON WATTLE BARKS.

## Part III.

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*Tanning School, Sydney Technical College.**(Read before the Royal Society of New South Wales, Dec. 2, 1931.)***Introduction.**

Some years ago, an investigation was commenced of the tanning value of certain New South Wales Wattles belonging to the so-called *Acacia decurrens* group. Botanical material was collected, together with bark samples, in order to determine whether the various members of this group could be easily recognised. Another object of the investigation was to determine whether, by the establishment of small plantations from seed obtained from trees which had been proved to yield a bark with high tannin content, it would be possible to improve the average tannin yield from locally grown wattles. Unfortunately, the necessary assistance to carry out this project was not made available, and pressure of other work has so far prevented the fulfilment of the scheme. From an examination of the analytical figures given for the barks of *Acacia mollissima*, it is very evident that New South Wales possesses excellent potential parent trees.

It has been generally recognised that *Acacia mollissima* yields the best tan bark of this group, and therefore especial attention was devoted to the analysis of a number of barks from different localities to determine whether the high yield was generally consistent.

The *Acacia decurrens* group was regarded by Maiden<sup>1</sup> as containing the following principal varieties: (a) var. *normalis* Benth., now described as *A. decurrens* Willd.; (b) var. *mollis* Lindl., now *A. mollissima* Willd., (c) var. *pauciglandulosa*, F.v.M., now *A. irrorata*, Sieber; (d) var. *Leichhardtii*, Benth., now *A. Arundelliana*, Bailey; (e) var. *dealbata*, F.v.M., now *A. dealbata* Link, and in addition there is another species, *A. filicifolia*, Cheel and Welch. There also appears to be a very definite form occurring over a fairly wide area which can best be regarded as a variety of *A. mollissima*, but further data is required. The "decurrens" group has in common, wattles with feathery bipinnate leaves, which are decurrent on the stems, and flowers arranged in heads.

After a careful examination of a large amount of botanical material, there does not appear to be any doubt but that these species are well established, and can be easily differentiated, and that the limits of variation are such that there need be no confusion between them.

In the following descriptions, only general and leaf characters are given. Floral characters have not been detailed, since wattles are only in flower for a short period during the year, and it is important to be able to separate the species when flowers are absent. A key to the identification of the species is given at the end of the paper.

#### **Bark Analyses.**

The results given under bark analyses are from butt samples, and can be regarded as the maximum for the tree, since, in general, tannin content varies directly as bark thickness. All analyses have been corrected to a standard moisture content of 11.5%, the "insolubles" being obtained by subtracting the sum of the tannin, soluble non-tannins and water, from 100.

The bark thickness is that obtained by measurement of the air-dry bark, and has been given with the analyses, since it must be regarded as an important factor. At the same time, exceptions undoubtedly occur which may be due to other influences, such as rate of growth and its relation to the proportion of old cells in the bark, and possibly physiological variations in the individual tree. This is referred to in our earlier work.<sup>2</sup>

The major works on wattle barks, generally, are those of Maiden<sup>3</sup> and, later, Coghill<sup>4</sup>. These are referred to under the various species, but attention should also be drawn to the analyses made by Blockey<sup>5</sup> of samples sent by Maiden to the Yorkshire College. According to these results, *A. mollissima* showed a lower tannin content than *decurrens* (*normalis*) or *Arundelliana* (*Leichhardtii*), and is little better than *irrorata* (*pauciglandulosa*). The results are based on single samples, which might not be representative.

Wind<sup>6</sup> gives analyses of barks from young trees (two-three years) grown in the Dutch East Indies, including the *A. decurrens*, var. *normalis*, *dealbata*, *mollissima* and *pauciglandulosa*; *mollissima* and *pauciglandulosa* are grouped together, and the tannin content varies from 20.46—24.33%.

Many analyses of *Acacia* barks cultivated abroad are also tabulated in the valuable bulletins of the Imperial Institute.<sup>7</sup>

Dekker<sup>8</sup> tabulates a number of analyses, chiefly based on Maiden, Blockey, and Zimmerman.

A very complete investigation has been made by Williams<sup>9</sup> of the bark of *A. mollissima*, grown in South Africa. This species has undoubtedly proved its worth under cultivation.

<sup>2</sup> N—December 2, 1931.

Chauvel<sup>10</sup> gives the tannin content of bark samples from four and six-year old trees of *A. mollissima*, grown in Madagascar, as 43.5 and 35.2%, respectively, and of *A. dealbata* as 23.8%.

Shinn<sup>11</sup> gives tannin values of *A. decurrens*, *A. mollissima* and *A. pycnantha*, grown in California, as 42.5, 46.0 and 41.8%, respectively, and states "that the superior value of *A. decurrens mollis* (i.e., *A. mollissima*) is plain."

Additional references are to be found in our earlier work.

ACACIA DECURRENS, Willdenow<sup>12</sup> (*A. decurrens* var. *normalis*, Bentham).

#### BLACK WATTLE.

This is evidently the species referred to by Bentham<sup>13</sup> as var. *normalis*, although he describes the leaflets as long and narrow, usually 3-4 lines (5-7 mm.), whereas usually they are at least 10 mm. in length. Maiden<sup>1</sup> followed Bentham in regarding this species as var. *normalis*. It is very distinct from the other species, and the variety has been dropped.

*Description*: A medium-sized tree, reaching a height of 40 feet and 15 ins. in diameter; bark usually smooth.

Leaves and branchlets tomentose when young, becoming almost glabrous or lightly sprinkled with hairs. Leaves very decurrent with prominent angles on the branchlets; up to 200 mm. in length.

Pinnae, opposite; 5-12 pairs; up to 80 mm. in length.

Glands prominent, usually one at the base of each pair of pinnae, or, rarely, an additional one on rhachis below junction of pinnae.

Pinnules widely spaced, often with an interval equal to four times the width of the pinnule between each; alternate

or opposite; narrow linear, inclined to become semi-terete; 8-18 mm. in length, usually about 10 mm.;  $\frac{1}{2}$ -1 mm. in width; occasionally leaves with flat pinnules up to  $1\frac{1}{2}$  mm. in width may occur together with more linear leaves on the same branchlet.

Flowering period about August. Pods ripen in about six months.

*Range*: Chiefly confined to moderately high elevations, e.g., Bargo, Thirlmere, Moss Vale and Marulan districts. Does not appear to occur on the coast or at high elevations, except under cultivation.

## TANNIN ANALYSES.

Moisture 11.5%

Bark Thick- ness (mm.)	Tannin	Non-Tannin	Locality
6-7	45.4	9.6	Bargo
5	45.2	10.0	Bargo
3	44.5	10.6	Bargo
5-6	43.3	10.6	Bargo
5	41.9	11.6	Bargo
3	40.3	11.8	Bargo
8	39.5	9.9	Bargo
5	36.0	13.5	Bargo

Maiden<sup>3</sup> gives the results of only two barks which, if analysed by modern methods, would probably give figures comparable with those now obtained. Coghill<sup>4</sup> gives two analyses from Victorian grown trees, and one from Gosford, N.S.W., the results being in the vicinity of 40% tannin; these barks are evidently from cultivated trees, since *A. decurrens* does not occur in these localities.

The results of our analyses show that *A. decurrens* ranks close to *A. mollissima*, and must be regarded as

yielding a useful bark. Further work is necessary to determine whether the yield of bark may be greater than that of *A. mollissima* under certain conditions.

ACACIA MOLLISSIMA. Willdenow<sup>14</sup> (*A. decurrens* var. *mollis*, Lindley<sup>15</sup>).

#### BLACK OR GREEN WATTLE.

This species, which was first described by Willdenow in 1809, was regarded as variety *mollis* of *A. decurrens* by Bentham<sup>13</sup>, and Maiden<sup>1</sup> supported this view since, in his opinion, the other varieties of *A. decurrens* passed by gradation, one into another. Mueller<sup>16</sup> gave it specific rank. The economic importance of this species, together with the fact that it can be readily recognised in the field, or as herbarium material, has resulted in Willdenow's name being now almost universally adopted.

A large collection of botanical and bark specimens has been made from New South Wales, and through the courtesy of the various Forestry Departments, material was also obtained from trees grown in Victoria, New Zealand and South Africa. A comparison has also been made with herbarium specimens from Tasmania, and there does not appear to be any doubt but that the mainland and Tasmanian material are specifically identical.

*Description:* A medium-sized tree, up to 45 feet in height, and 18 ins. in diameter. Bark usually smooth, dark brown in colour, occasionally in old or diseased trees showing ross.

Leaves and branchlets densely tomentose when young, and golden yellow in colour, older leaves and branchlets becoming more glabrous, until they may be only covered with scattered hairs, the upper surfaces of the leaves

practically glabrous. Branchlets occasionally slightly glaucous.

Pinnæ usually opposite, occasionally both opposite and alternate in the same leaf; broad linear in outline; 6-20 pairs, rarely less than 8; 20-60 mm. in length, usually about 45 mm.

Glands, 1-4 on the rhachis between each pair of pinnæ, occasionally almost entirely solitary and rounded, but varying from 1-3 in the same leaf; where crowded, they are often elongated and confluent. Secondary glands very rarely present on the bases of the pinnæ.

Pinnules crowded, occasionally overlapping, more rarely spaced so that the gap may exceed the width of the pinnule; usually alternate; spathulate to linear-oblong; usually obtuse, rounded or truncate, sometimes shortly acute; angle of attachment varying from 45°-90°; usually 3-5 mm. in length; 0.5-0.75 mm. in width.

Flowering period, October to December, usually November. Pods do not ripen for about 12 months.<sup>17</sup> Pods inclined to be rough, usually contracted between seeds.

*Range:* In New South Wales, it reaches its maximum development on the South Coast, below Nowra, especially in the Eden district. It is also common on the southern highlands in the Bowral-Mittagong area. It is not common north of Sydney. A more glaucous form is found in the Blue Mountains and Sydney districts. It does not occur at high elevations, nor does it seem to occur west of the Dividing Range. It is common in Victoria and Tasmania, but it is doubtful whether it occurs in Queensland. In N.S.W. it generally prefers well-drained slopes and is not commonly found near water.



## TANNIN ANALYSES.

Moisture 11.5%

Bark Thick- ness (mm.)	Tannin	Non-Tannin	Locality
10	53.5	8.3	Pericoe
3-4	51.9	9.1	Kangaroo Valley
7-8	49.8	8.8	Eden
7-8	49.6	9.2	Lal Lal, Victoria
6	49.4	11.1	Falls Creek
6-7	48.9	9.0	Pericoe
7	48.4	7.1	Kangaroo Valley
6	48.4	8.5	Falls Creek
5-6	48.1	9.2	Pericoe
6-7	47.9	9.1	Pericoe
5-6	47.8	7.5	Pericoe
6	47.6	9.5	Cedara, Natal
—	47.6	8.9	Falls Creek
5-6	46.5	8.8	Nilgiris, India
7	46.3	11.8	Falls Creek
5-6	46.2	8.5	Eden
5	46.0	9.8	Pericoe
5-6	45.8	10.2	Nowra
3-4	45.6	9.5	Lal Lal, Victoria
4-5	45.5	9.6	Nowra
4-5	45.3	10.5	Bowral-Mittagong
7-8	45.0	8.9	Rotorua, N.Z.
6	44.9	8.1	Pericoe
5	44.8	8.9	Fitzroy Falls-Bowral
4-5	44.0	7.3	Eden
3-4	43.9	7.8	Nowra
3-4	43.9	10.5	Nowra
3-4	43.9	10.8	Bowral-Mittagong.
5-6	43.8	9.9	Pericoe
5-6	43.8	8.0	Cedara, Sth. Africa
8-9	43.6	8.1	Eden

Bark Thick- ness (mm.)	Tannin	Non-Tannin	Locality
3-4	43.5	9.9	Delatite, Victoria.
4-5	43.5	9.9	Mt. Cole, Victoria
4-5	43.3	9.2	Nowra
5.	43.0	11.5	Delatite, Victoria
5-6	42.7	10.6	Pericoe
5	42.7	8.3	Cedara, Sth. Africa
—	41.7	7.4	Moruya
4-5	40.2	7.8	Eden
4-5	40.2	10.1	Bateman's Bay
4-5	39.0	12.6	Sth. Africa
2-3	38.8	7.8	Bateman's Bay.
5	37.5	11.5	Rotorua, N.Z.
6-7	37.5	6.8	Pericoe
2-3	35.4	10.7	Bateman's Bay
5-6	34.6	8.1	Pericoe
3-4	32.9	10.0	Bateman's Bay
5	28.1	6.6	Mt. Cole, Victoria

Maiden<sup>3</sup> gives figures for *A. mollissima* analysed by the old Lowenthal Method. One analysis shows 69.33% extract, 36.4% tannin; analysed by modern methods such a figure for extract or total solubles would give at least 50% tannin.

Coghill<sup>4</sup> gives the results of analyses from Queensland, N.S.W., Victoria and Tasmania. Only one analysis is given for a N.S.W. sample, and this shows 22.8% tannin from a Gosford tree. It is very doubtful whether *A. mollissima* occurs naturally in the Gosford district, and from this analysis, compared with our results, it appears doubtful whether the identification is correct. The Queensland sample from Imbil (Coghill<sup>4</sup>) 27.2%, unless cultivated, is also doubtful. Cultivation in South Africa, British East Africa, India, New Zealand and elsewhere, has shown prac-

tically without exception that this species produces a bark with a high tannin content, and this is confirmed by our analyses not only of local barks, but also of samples from New Zealand, India and South Africa.

Taking into consideration bark thickness, the following results are obtained:—

Bark Thickness (mm.)	Tannin	No. of Samples
2-3	37.1	2
3-4	43.7	7
4-5	42.6	8
5-6	42.7	15
5-6	42.7	5
6-7	46.4	7
7-8	47.8	5
8-9	43.6	1
9-10	53.5	1

These show a gradual increase in tannin content corresponding to an increase in bark thickness, with one exception, namely 8-9 mm., which represents, however, only one sample. There appears to be ample justification for the belief of the tanner that "heavy" bark gives the best results. In an examination of the actual analyses, however, it is interesting to note that the second highest result, namely 51.9% tannin, was obtained from a comparatively thin bark, and as already mentioned, there is more in the problem than bark thickness alone when dealing with individual trees.

Of the samples analysed two gave over 50%, 38 over 40%, 7 over 30% and one under 30% tannin.

The remarkable tannin content of 53.5% obtained from a sample of *A. mollissima* places it well on a level with the highest figures obtainable from *A. pycnantha*.

Proctor<sup>18</sup> gives analyses of three samples of *A. mollissima* supplied to him by Maiden, with tannin varying from 36-41%, and records 40-50% for *A. pycnantha*. Proctor's figures for *A. mollissima* may be legitimate for bulk samples but they should not be compared with what are evidently analyses of picked samples of *A. pycnantha*, since in our opinion the relative value of the two barks is by no means in this ratio. Bennett<sup>19</sup> gives a figure of only 36% tannin for *A. mollissima*.

It is desirable that attention should be drawn to the fact that butt samples of *A. mollissima* bark can also be found to give tannin results of 50% or more and it is apparent that justice has not been done to this wattle.

The apparent inferiority of the bark has been no doubt largely due to the close resemblance, in the eyes of the layman, of the tree to others which possess barks of definitely lower tannin content, and this is probably the reason why "South Coast" bark is regarded by tanners as being inferior to "Adelaide" bark (*A. pycnantha*). Provided *A. mollissima* is kept distinct there seems to be little reason why this inferiority should exist.

*ACACIA IRRORATA*, Sieber<sup>20</sup>, (*A. pauciglandulosa*, F.v.M.)

GREEN WATTLE OR BLUE SKIN.

*A. irrorata* was placed by Bentham<sup>13</sup> under *A. dealbata*, the locality given being Port Jackson and the Blue Mountains. *Acacia dealbata* does not occur in the Port Jackson district, whilst *A. pauciglandulosa* is one of the commonest feather leaved wattles both here and on the Blue Mountains. Cheel<sup>21</sup> has suggested that *A. irrorata* is identical with *A. pauciglandulosa*, and is of the opinion that *A. irrorata* should replace *A. pauciglandulosa*, due to the priority of Sieber's description. Without evidence to the contrary, Cheel's suggestion has been adopted.

*Description:* A medium sized tree up to 60 feet in height and 18 ins. in diameter, bark commonly brownish green, bright green on young trees and branches.

Young leaves and branchlets often very woolly tomentose; shoots golden yellow; hairs usually tubercular, the small tubercles causing the rhachis of the leaves and decurrent angles on the branchlets to become scabrous, a feature which readily separates this species from the others; older leaves sprinkled with hairs; length 60-160 mm., not usually exceeding 100 mm.

Pinnæ usually opposite, inclined to be lanceolate in outline, usually 6-12 pairs; 25-60 mm. in length.

Glands, few in number or occasionally wanting, often only a single gland at the base of the upper pair of pinnæ, occasionally a single gland at the base of each of four upper pairs of pinnæ, sometimes one gland at base of lowest pair of pinnæ; very rarely two glands in contact.

Pinnules, usually very crowded and overlapping—rarely slightly spaced; opposite or alternate; linear to narrow lanceolate, shortly acute or acuminate, not rounded; angle of attachment 30°-60°; not exceeding 6 mm. in length, usually 3-5 mm.; about 0.5 mm. in width.

Flowering period about December. Pods take 12 months to ripen; often somewhat constricted between seeds.

*Range:* *A. irrorata* prefers moist situations, and is the common form found near creeks and watercourses in the Sydney district. It extends south along the coast to beyond Narooma, but does not occur in the Eden district, nor does it occur in Victoria. North of Sydney it is very prevalent, practically replacing *A. mollissima*; it extends into Queensland.

## TANNIN ANALYSES.

Moisture 11.5%.

Bark Thick- ness (mm.)	Tannin	Non-Tannin	Locality
3-5	35.1	9.4	Passchendaele, Q.
2-3	34.6	8.7	Nowra
3	33.4	8.6	Nowra
4	33.1	8.6	Nowra
2-4	33.0	10.5	Bundaberg, Q.
3-4	32.4	9.0	Nowra
2-3	31.9	9.2	Terrigal
2-3	31.6	8.6	Nowra
3-4	30.2	8.7	Terrigal
3	30.2	10.0	Terrigal
2	30.1	12.6	Terrigal
2-3	29.7	8.9	Terrigal
4-5	29.5	11.1	National Park
3	28.8	10.3	National Park
1-2	28.7	11.5	Cockle Creek—Cowan
4-5	28.4	9.5	National Park
1-2	28.2	11.1	Nowra
3-4	28.2	8.7	Nowra
2	27.6	10.6	Terrigal
3-4	26.6	9.4	Terrigal
4-5	26.4	8.6	National Park
3	25.8	7.6	National Park
2-3	25.5	10.1	Terrigal
4	25.3	5.2	National Park
5-6	25.3	6.2	National Park
—	24.9	12.3	Nowra
—	24.4	7.2	Gosford
—	22.6	8.1	Nowra
3-4	22.4	7.9	National Park
2	20.7	12.1	National Park
2	20.6	10.5	Nowra
—	19.9	9.8	Bateman's Bay.

Maiden<sup>3</sup> gives the results of three analyses, two of which show extract figures of 52 to 53%, corresponding to a tannin % rather higher than those given by our analyses. Coghill<sup>4</sup> gives some seven analyses of barks from Queensland and New South Wales, with results varying from 36.1% to 23.4% tannin. The results of our analyses, with a maximum of 35.1%, and a minimum of 19.9% tannin, prove conclusively that this is an inferior bark, especially when it is taken into consideration that these results are from butt samples, many being from large, well-grown trees, in order to obtain as high a tannin content as possible. The bark, even from large trees, is usually thin.

ACACIA ARUNDELLIANA, Bailey<sup>22</sup> (*A. decurrens* var. *Leichhardtii*, Benth<sup>13</sup>)

#### SILVER WATTLE.

This *Acacia* was raised to specific rank by Bailey. Mueller and Maiden<sup>23</sup> were also of the opinion that this was a distinct species and called it *A. O'Shane'sii*, but gave no description. Apparently, Maiden<sup>3</sup> later allowed the name *O'Shane'sii* to drop, since the variety *Leichhardtii* is restored and the statement is made that it is impossible to separate it from var. *pauciglandulosa*, since it may be looked upon as var. *pauciglandulosa* with long hairs, or var. *pauciglandulosa* is var. *Leichhardtii* with short hairs. Similar statements are made in the Forest Flora<sup>1</sup>.

Apart from the fact that this tree yields a much superior bark to *A. irrorata* (*pauciglandulosa*), it appears to be quite distinct from that species and can readily be recognised in the field.

*Description*: A medium sized tree reaching a height of 45 feet and 18 ins. in diameter. According to Maiden<sup>1</sup>, trees have been noted up to 36 ins. in diameter. Bark smooth, brownish in colour.

Leaves and branchlets very pubescent, much more so than *A. irrorata*; young shoots very golden yellow; branchlets not scabrous; foliage very dark green and not glossy. The tree can be readily separated from *A. mollissima* or *A. irrorata* in the field by this character. Older leaves almost glabrous and decidedly paler on the under surface (the only member of the group here described which shows this feature): up to 120 mm. in length. The foliage is more delicate and graceful than that of the other members of the "*decurrrens* group."

Pinnæ usually opposite; 7-20 pairs; 25-45 mm. in length, usually 30 mm.

Glands intermediate in number between *A. irrorata* and *A. mollissima*, e.g., they may extend for half the length of the rachis, or more rarely may be quite wanting, sometimes one at top, one at middle and one at bottom of leaf; practically always solitary to each pair of pinnæ.

Pinnules rarely crowded, usually spaced with intervals up to twice width of pinnule; opposite or alternate; linear oblong to narrow ovate; obtuse or shortly acute; angle of attachment  $45^{\circ}$ - $90^{\circ}$ ; 3-5 mm. in length (Q), often not exceeding 2 mm. (N.S.W.); 0.6-1.0 mm. in width.

Flowering period about August. Pods take about 6 months to ripen; thin, often glaucous.

*Range*: New South Wales, chiefly confined to a coastal area of about 400 sq. miles in the Clyde River district; not occurring much south of Mogo or north of Cockwhy Creek; it prefers the beds of watercourses. It is remarkable how this species is very common in this area yet does not seem to occur elsewhere in New South Wales. The local explanation is that these trees have grown from seeds brought from Tasmania! by Ludwig Thomsen about 60 years ago. It



occurs also in Southern Queensland. Bark samples analysed were chiefly from southern New South Wales.

TANNIN ANALYSES.  
Moisture 11.5%.

Bark Thick- ness (mm.)	Tannin	Non-Tannin	Locality
7	43.5	7.2	Bateman's Bay
5-6	40.9	7.9	Bateman's Bay
6	38.8	6.1	Bateman's Bay
7	38.8	5.3	Bateman's Bay
4-5	35.6	6.3	Bateman's Bay
2-3	32.6	8.8	Bateman's Bay
1-2	27.1	13.0	Kilkivan (Q.)

This bark is the so-called "Silver Wattle" of the South Coast.

Maiden<sup>3</sup> gives the results of four analyses from the South Coast. The highest tannin value being 25.25%. Brunnich and Jeffries<sup>24</sup> give an analysis of a Queensland sample with a tannin content of 17.46%. From our analyses it is evident that this species yields a very useful bark, and is well worthy of further investigation, although nothing is known of its silvicultural possibilities.

ACACIA DEALBATA, Link<sup>25</sup>.

SILVER WATTLE.

This species was separated from *A. decurrens* by Benth<sup>13</sup>. Mueller, according to Benth<sup>13</sup>, regarded this as a variety, but later<sup>16</sup> adopted the same view as Benth<sup>13</sup>. Maiden<sup>1</sup> placed it as a variety of *A. decurrens*, stating that it "is an extreme form of var. *mollis*."

Our experience has been that the bark is so inferior, that no good purpose could be served by linking it with *A. mollissima*; moreover, the morphological characters seem sufficiently distinct for Link's name to be adopted.

*Description:* Usually only a small tree in New South Wales, rarely exceeding 30 feet in height and 12 ins. in diameter, but recorded as reaching a large size, up to 11 feet girth and over 100 feet in height, in Tasmania. Bark in New South Wales trees often heavily rossed.

Leaves and branchlets covered with a short pubescence especially when young, becoming more glabrous with age. Young shoots often yellow, but colour usually less pronounced than in other species. The leaves and branchlets are normally pale green in colour, and appear lighter due to the white hairs; in addition, the presence of a white waxy bloom gives the tree a silvery appearance. Whilst the glaucousness of the branchlets and leaves is variable, thus one part may be quite white and another pale green and free from bloom, the general whitish appearance is very distinct from that of the other species. Leaves up to 160 mm. in length but usually much shorter.

Pinnae almost always opposite, 8-30 pairs, usually 10-20; 15-35 mm. in length.

Glands single at junction of pairs of pinnae.

Pinnules usually crowded, more rarely slightly spaced; opposite or alternate; broad linear; obtuse; angle of attachment usually about  $60^{\circ}$ ; usually 2-5 mm. long and 0.6-0.75 mm. wide, rarely occasional leaflets may be 9 mm. long and up to 1 mm. wide.

Flowering period August and September. Pods take about six months to ripen.

*Range:* Although recorded by Bentham for Port Jackson, this does not appear to be correct, being confined to comparatively high elevations in New South Wales. It does not occur along the coastal strip. It occurs commonly in Victoria and Tasmania, and is recorded for Southern Queensland.

## TANNIN ANALYSES.

Moisture 11.5%.

Bark Thick- ness (mm.)	Tannin	Non-Tannin	Locality
4.5	36.6	7.0	Mt. Cole, Vic.
3.4	35.9	6.2	Delatite, Vic.
2	34.0	9.1	South Africa
4.5	32.3	8.4	Lal Lal, Vic.
4.5	31.5	6.1	Murraguldrie
3.4	30.7	8.1	South Africa
4	30.6	7.6	Mt. Cole, Vic.
3	30.0	9.9	South Africa
2.3	29.9	13.3	South Africa
2.3	29.7	8.5	Rotorua, N.Z.
2.3	28.4	9.7	Rydal
4.5	28.0	6.4	Delatite, Vic.
2.3	27.4	13.8	South Africa
2.3	26.1	9.8	Nundle
3.4	26.0	5.4	Murraguldrie
2.3	25.4	9.3	Rydal
5	24.9	7.2	Rydal
5	24.6	6.3	India
7.8	23.7	7.8	Rotorua, N.Z.
2.3	23.1	13.9	Lal Lal, Vic.
3.4	23.1	6.6	Burwood (cult.)
3.4	21.9	10.6	Nundle
5.6	21.0	8.9	Nundle
3.4	20.8	11.8	Nundle
1.2	20.5	8.1	Nundle
5.6	20.5	5.6	Rydal
3	20.3	9.2	Nundle
5.6	17.4	7.6	Nundle
2.3	16.1	8.9	Murraguldrie

A sample from Rotorua, New Zealand, with 47.6% tannin has been discarded since other trees from the same locality gave only 29.7% and 23.7% tannin. The botanical material supplied with the bark is undoubtedly *A. dealbata*. Coghill<sup>4</sup> records 22 analyses from Victoria and Tasmania, the highest being 32.3% and the lowest 13.9% tannin. Maiden's<sup>3</sup> results are also consistently low. All the evidence to date confirms the view that *A. dealbata* yields an inferior bark, and this is shown clearly by the results given above for cultivated samples from New Zealand, South Africa and India, as well as for naturally grown material from N.S.W. and Victoria. Although the flowering periods are different, it is not advisable to cultivate this wattle with *A. mollissima*.

ACACIA FILICIFOLIA (Cheel and Welch<sup>26</sup>).

FERN-LEAVED WATTLE.

Apparently this species was regarded as one of the connecting links between several members of the *decurrrens* group, and was probably responsible for some of the confusion. It is quite distinct over the whole of the range.

*Description:* A medium sized tree reaching a height of 40 feet and a diameter of 18 inches. Bark smooth, brownish in colour. Leaves and branchlets tomentose, becoming more glabrous with age; branchlets often glaucous; leaves up to 170 mm. long.

Pinnæ usually opposite; 5-12 pairs; up to 75 mm. in length.

Glands numerous, 2-5 to each pair of pinnæ; separate or occasionally confluent; secondary glands often present, either on base of pinnæ or as many as 5 distributed along its axis.

Pinnules normally crowded; occasionally some leaves may show spacing of greater width than pinnules; opposite or alternate; narrow linear, often spathulate, shortly acute; angle of attachment from 30°-60°; usually 5-7 mm. long; usually 0.5-0.75 mm. wide, occasional leaflets up to 9 mm. long and 1.5 mm. wide.

Flowering period August to September, more rarely October. Pods probably take six months to ripen; broad.

*Range:* It extends along the slopes of the Dividing Range from Rydal to the Queensland Border. It appears to be rare on the coast except between Nowra and Clyde River, and is very common in damp situations about Yerriyong.

#### TANNIN ANALYSES.

Moisture 11.5%.

Bark Thick- ness (mm.)	Tannin	Non-Tannin	Locality
—	31.4	8.8	Nowra
3	31.4	10.5	Nowra
1-2	30.5	7.4	Nowra
3	30.1	5.7	Nowra
1-2	29.8	9.0	Nowra
—	29.2	7.2	Nowra
2	29.1	9.3	Nowra
2	28.6	7.5	Nowra
3-4	28.5	6.1	Nowra
3	25.6	8.5	Nowra
2	24.8	8.9	Nowra

From the results of these analyses this can only be regarded as an inferior bark, but further samples are desirable from some of the northern areas in which this species occurs. It is important that this species should

be recognised as inferior and not confused with *Acacia decurrens* or *A. mollissima*.

The following key to the identification of the species is based on leaf characters.

- (a) Glands never extending full length of rhachis:
  - (b) Pinnules narrow, acute, crowded, glands not usually exceeding 3 in number, rhachis and young stems scabrous = *A. irrorata*.
  - (b<sub>1</sub>) Pinnules broad obtuse, usually not crowded, glands often extending half length of rhachis; not scabrous = *A. Arundelliana*.
- (a<sub>1</sub>) Glands always extending full length of rhachis.
  - (c) Pinnules rarely or never exceeding 5 mm. in length.
    - (d) Leaves and stems usually glaucous = *A. dealbata*.
    - (d<sub>1</sub>) Leaves and stems rarely glaucous = *A. mollissima*.
  - (c<sub>1</sub>) Pinnules rarely under 5 mm. in length.
    - (e) Pinnules 8-18 mm. in length widely spaced = *A. decurrens*.
    - (e<sub>1</sub>) Pinnules 5-9 mm. long, usually crowded, never widely spaced = *A. filicifolia*.

In addition to these, there are several other allied species, e.g., *A. Jonesii*, Mueller and Maiden<sup>23</sup> and *A. pubescens*<sup>27</sup> R.Br., are both shrubs. *A. Muelleriana*<sup>28</sup> Maiden & Baker, is a shrub or small tree from the interior with sparse widely spaced pinnules. *A. Deanei*<sup>29</sup> (*A. decurrens* var. *Deanei*) Baker, is an interior shrub with a superficial re-

semblance to *A. mollissima*, but with few pairs of pinnae and coarser pinnules. *A. decurrens* var. *lanigera* Maiden<sup>3</sup> is an interior shrub or small tree with a densely hairy indumentum on leaves, stems and pods.

None of these is likely to be confused in the field with those species which have been described in this investigation.

#### SUMMARY.

An investigation has been made of the tannin contents of the barks of the principle Acacias belonging to the so-called "decurrens" group, and botanical material has also been critically examined. Six species which can be recognised as distinct are described, and details are given of their leaf and general characters, together with the results of a number of bark analyses, which are summarised in the following table:— (*see next page.*)

In reviewing the results of the analyses dealt with in this paper, it is apparent that the species can be divided into two main groups as far as the value of their barks is concerned. Thus *A. mollissima*, *A. decurrens* and *A. Arundelliana* can be placed in this order of merit in the superior group, and *A. filicifolia*, *A. irrorata* (*pauciglandulosa*) and *A. dealbata* in the inferior group.

On the whole those species with thin barks give low tannin contents, but even with barks of similar thickness the inferior species possess lower tannin content than those belonging to the superior group.

*Acacia mollissima* is the outstanding species with regard to tannin content, although *A. decurrens* and *A. Arundelliana* also yield useful barks, and may prove of value under conditions which are unfavourable to *A. mollissima*.

THE FOLLOWING TABLE SUMMARISES THE RESULTS  
OF THE ANALYTICAL WORK.

Bark thickness in mm.	Tannin Content of all Barks.									
	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	Mean
<i>A. mollissima</i> . . . .	28.1(1)	37.1(2)	43.7(7)	42.6(8)	42.7(15)	46.4(7)	47.3(5)	43.6(1)	53.5(1)	44.0(48)
<i>A. decurrens</i> . . . .	—	—	42.4(2)	—	41.6(4)	45.4(1)	—	39.5(1)	—	42.0(8)
<i>A. irrorata</i> . . . .	28.4(2)	28.0(9)	29.6(11)	28.5(5)	25.3(1)	—	—	—	—	28.0(32)
<i>A. Arundelliana</i> . . . .	—	—	—	—	39.8(2)	—	40.6(2)	—	—	36.6(7)
<i>A. dealbata</i> . . . .	20.5(1)	26.7(9)	26.1(8)	31.8(5)	21.7(5)	—	23.7(1)	—	—	26.2(29)
<i>A. flicifolia</i> . . . .	30.1(2)	27.5(3)	28.9(4)	—	—	—	—	—	—	29.0(11)

(Figures in brackets represent number of samples analysed.)



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AN UNDESCRIBED SPECIES OF WATTLE.  
*ACACIA FILICIFOLIA*.

By E. CHEEL and M. B. WELCH, B.Sc., A.I.C.

(With Plates VII and VIII)

(Read before the Royal Society of New South Wales, Dec. 2 1931)

Frutex aut arbor 3-5 m., nonnunquam 12 m. altus, foliis pinnatis 5-10 jugis pinnarum cum 2-3 glandulis (nonnunquam 4-5) inter jugos pinnarum, glandula purva ad basin pinnarum inter jugos inferiores foliolarum, foliolis 35-45, 5-9 mm. longis, primo pubescentibus deinde glabrescentibus, floribus in racemis, legumine 8 cm. longo, 1.5 cm. lato, glauco.

Tree usually 9 to 15 feet tall, but occasionally up to 40 feet. Branches more or less slightly angular, but not winged, the young twigs as well as the rhachis rather densely tomentose, but with age becoming glabrous and quite glaucous.

Leaves pinnate with 5 to 10 pairs of pinnæ, the rhachis raised to a well-defined ridge with 2 to 3 glands between each pair of pinnæ or occasionally 4 or 5 glands sometimes becoming confluent as in *A. mollissima*. In addition to the glands between the pinnæ there is usually a smaller gland at the base of each pinnæ between the lower pair of leaflets. Leaflets numerous (usually 35-45), rather inclined to be more spreading and fern-like than the other forms of the *A. decurrens* group; at first pubescent, but glabrous with age; usually 5-7 mm. long, but occasionally up to 9 mm. long. Flowers in racemes, the individual flowers varying from 25 to 30 in each head, mostly 5-merous

Calyx, shortly lobed, ciliate; petals, almost glabrous, sparingly ciliate; pods 8 cm. long x 1.5 cm. broad, glaucous; seeds reniform, 5 x 2-3 mm.; funicle short, slender at the base, with a thickened aril.

This species has been previously mistaken as a form of *A. decurrens*, and also confused with *A. mollissima* and *A. dealbata*. It is quite distinct from *A. decurrens*, which has very prominently angled branches, and branchlets more or less winged and mostly quite glabrous. It also differs from *A. mollissima*, which has smaller leaflets and a much narrower pod, and the flowering season is during November and December, whereas *A. filicifolia* flowers during August to October. Its nearest affinity is with *A. dealbata*, but the pinnae of *A. filicifolia* are not so silvery and less numerous, and the leaflets are longer and more glabrous with age than those of *A. dealbata*.

*Distribution*.—Goulburn River (R. T. Baker, 1892); Kelgoola (R. T. Baker, 1895); Mt. Baker, Corricudgy Range (R. T. Baker, 1897); Nullo Mtn., Rylstone (R. T. Baker, 1898); Armidale (C. F. Laseron, 1907); Acacia Creek (W. Dunn, Aug., 1909); Glen Innes (W. Stewart, Aug., 1910, and J. L. Boorman, March, 1917); Torrington (J. L. Boorman, October, 1911, in flower; January, 1911 and 1916, pods); Howes Mtn., Singleton (J. L. Boorman, Aug., 1913); Pheasants Creek, Glen Elgin (J. L. Boorman, Dec., 1913); Capertee (J. L. Boorman, Sept., 1915); Yerrilyong (Coombs and Welch, 1923); Nowra (Coombs and Welch, 1923); Rydal (C. F. Laseron, 1924); Shallow Crossing, Clyde River (A. McKay, 1928); Guyra (E. N. McKie, 1928); Tenterfield (Whereat, no date).

In its southern distribution it is found chiefly on alluvial flats in moist positions.

*Economics*.—Analyses of the bark for tannin have proved disappointing with respect to bark collected from the South Coast district, and it can only be regarded as distinctively inferior to *Acacia mollissima*. The barks so far examined yield from 25-32% tannin.<sup>1</sup>

#### REFERENCE.

<sup>1</sup>Welch, Coombs and McGlynn. Notes on Wattle Barks—Part III Jour. Roy. Soc., N.S.W., 65:226 1931.

#### EXPLANATION OF PLATES.

Plate VII.—*Acacia flicifolia*, Cheel & Welch—Flowering branch.

Plate VIII.—*Acacia flicifolia*, Cheel & Welch—Fruiting branch (Pods).



*Acacia filicifolia*, Cheel and Welch. (Flowering branch )





• *Acacia filicifolia*, Cheel and Welch. (Fruiting branch)





## NOTES ON THE SHRINKAGE OF WOOD.

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Very little data is available on the amount of lateral shrinkage which occurs during the seasoning of many Australian woods, i.e., during the drying from a green to an air-dry condition.\* It has long been recognised that shrinkage varies considerably in different woods, evidently due to some inherent character within the wood. For many industrial purposes it is essential that a wood should be used which shows a minimum shrinkage; in fact excessive shrinkage is to be avoided in general. Furthermore, in cutting green timber, an allowance has to be made in order that the seasoned wood should not be under size, and some idea of the amount of shrinkage is therefore necessary.

A theoretical explanation of shrinkage is that the micellae or molecular aggregates forming the cell wall are, in green wood, held apart by water films. During the process of drying, these films contract, allowing the

\* Chapman gives the results of some observations made on seven Eucalypts and three Pines during his investigation of their mechanical properties.

Chapman, R. W., "The Strength of South Australian Timbers," Bull. 9, Dept. of Forestry, South Australia. 1922.

micellae to approach each other more closely with the consequent shrinkage of the wood.

In general the shrinkage parallel to the grain is extremely small, and for most purposes can be neglected. Shrinkage in a tangential direction is usually regarded as approximately twice that of radial shrinkage; the smaller radial shrinkage being possibly due to the stiffening action of the ray cells which have their long axis at right angles to the normal wood tissue.

Any figures for shrinkage must be used, however, with caution, since this property can be influenced by a number of factors. Even mean figures based on many samples only indicate general behaviour, and not necessarily that of an individual sample. The results given herewith are not based on a large number of samples, and may, or may not, indicate the average behaviour of the species. They have been obtained from a number of commercial samples and represent the actual shrinkages measured on these woods.

Shrinkage is influenced in the same wood by variation of density; thus the following average relationship has been suggested†:—Specific gravity  $\times 17$  = tangential shrinkage, green to oven dry, and specific gravity  $\times 9.5$  = radial shrinkage, green to oven dry, i.e., the heavier the wood the greater the shrinkage, although there are many exceptions to this rule.

Shrinkage is also influenced by the rate of drying; wood rapidly dried usually shrinks less than when allowed to dry slowly, owing to the wood, during rapid drying, being

† Relation of Shrinkage and Strength Properties of Wood to the Specific Gravity. U.S.D.A. Bull. 676, 1919.

more liable to set in an expanded condition. Again, the ratio of tangential to radial shrinkage usually decreases with an increase in density, but this again is not always constant.

Whereas shrinkage implies the normal contraction of the wood due to moisture losses, there is a further complication, in that abnormal shrinkage may be caused by the phenomenon known as "collapse" in which, due to very large tensile stresses caused by water leaving the cell cavity, the cell walls are drawn together or collapsed. Certain Eucalypts,\* especially those of low density, are very liable to this defect, the wood in extreme cases becoming extensively corrugated. Where slight collapse occurs, it is practically impossible to separate it from ordinary shrinkage.

The figures given below were obtained by cutting small sections 1 inch long in the direction of the grain 4 inches wide and 1 inch thick, from wood which was obtained as soon as possible after sawing from the log, being wrapped in damp paper to minimise moisture losses. These sections were weighed and measured, and the volume determined; they were stored inside and measured weekly to the nearest .001" for periods varying from three to twelve months, the average width being taken as the mean of the maximum

\* Elliott mentions that "the additional size allowance which many millers find it necessary to make in sawing timber which is prone to collapse, commonly amounts to more than 20% over and above the allowance necessary to cover ordinary shrinkage and machining."

Elliott, C. S., "Collapse of Timber." Reprint from Journal, C.S.I.R., November, 1930.

and minimum widths after the samples had reached an equilibrium moisture condition. A similar sized sample, cut from the same board as the specimen which was air-dried, was also weighed and measured etc., and dried at 102° C. for some days to constant weight and again weighed and measured. From these results the density at air dry volume and weight; density, green volume and oven dry weight; % shrinkage green to air dry; % shrinkage green to oven dry, and volumetric shrinkage, green to oven dry, has been calculated. The moisture content was determined on sections cut adjacent to the samples which were used for shrinkage tests.

In column 1, the weight per cubic foot is based on air-dry volume and weight, and is useful practically, since it is in this condition that wood is, or should be, used for most purposes. In column 2 the density is based on green volume and oven dry weight, and although such a combination is, of course, impossible in practice, the results are useful for comparative purposes, being based on less variable factors. Actually, slight variations in the moisture content of air dry wood do not appreciably affect the density, since the gain in weight due to the absorption of moisture is offset by the increase in size due to swelling. The green volume and oven dry weight (Wd/Vg) density figures have one other advantage, in enabling a determination of the weight per cubic foot of the green wood to be made, a figure which is often required in determining the weight of logs, green sawn timber, etc. Thus, if the Wd/Vg weight per cubic foot is  $x$  lbs., and the moisture content  $y$  %, then the density of the green timber is  $(100 + y)x$

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100 lbs. per cubic foot.

The percentage shrinkage from a green to an air dry condition, based on the green size, is given in column 3. Column 4 gives the shrinkage from a green to an oven dry condition, and was obtained from samples which were not allowed to air season before being placed in the oven. As a result the figures are in many cases lower than would have been obtained if the wood had been previously allowed to season slowly, and accounts for certain anomalies where the oven dry shrinkage approximates to, or is less than, the air dry figure. Volumetric shrinkage given in column 5 was obtained by actual measurement of the shrinkage of small specimens from a green to oven dry condition, although it is possible to calculate this figure if the tangential and radial shrinkages are known. It serves as a basis for the comparison of the relative shrinkages of the various woods. Moisture percentages given in column 6 were obtained from sections cut as soon as possible after the arrival of the test pieces. Although those forwarding the specimens used were asked to obtain the wood when freshly cut from the green log and to wrap it in wet paper to reduce moisture losses it is evident from some of the figures that the wood had commenced to dry. Since, in general, shrinkage (not collapse) is not pronounced till the fibre saturation point in the vicinity of 30% moisture is reached, the actual effect of some moisture loss on shrinkage would not be very important, but where the moisture figures given are below this amount, i.e., 30%, the shrinkage figures are likely to be below normal. The moisture figures are of value in enabling the weight per cubic foot, wet volume and weight, to be calculated, and also in most cases giving some idea of the amount of water present in freshly sawn green timber. The last column indicates the direction in which the test pieces were sawn.

## AUSTRALIAN TIMBERS.

	1	2	3	4	5	6	7
<i>Acacia melanoxylon</i>	44.3	37.7	1.4	3.3	8.0	98.6	Q.
Blackwood	46.6	39.8	1.9	4.2	9.0	90.3	Q.
	44.0	40.5	3.6	6.3	7.9	100.4	B.
<i>Ackama Muelleri</i>	35.9	32.7	3.3	5.5	8.6	114.1	B.
Red Corkwood	38.6	32.0	6.4	10.0	18.9	96.7	Q.
	40.3	32.0	9.6	14.3	18.8	96.8	B.
<i>Agathis Palmerstoni</i>	31.2	24.8	1.6	2.9	6.5	19.5	Q.*
Queensland Kauri	29.8	25.2	2.6	4.2	16.1	63.7	Q.
<i>Alstonia scholaris</i>	25.2	20.0	1.6	3.8	8.5	88.9	Q.
Milkwood	23.4	—	3.2	—	—	97.0	B.
<i>Araucaria Cunninghamii</i>	38.8	32.6	4.3	6.0	12.0	52.2	Q.
Hoop Pine	35.6	26.6	2.8	3.8	11.1	122.9	Q.
	31.8	26.9	3.4	5.5	14.5	58.3	B.
	32.1	26.4	5.6	8.3	13.1	95.8	B.
<i>Callitris glauca</i>	39.5	33.8	2.5	4.4	10.4	52.0	Q.
Cypress Pine	39.8	34.3	2.8	4.7	8.2	29.0	Q.
	50.2	36.6	2.9	5.0	10.3	29.6	Q.
	47.0	37.6	2.7	4.8	9.2	24.3	B.*
	44.9	37.6	3.8	5.5	10.9	41.2	B.
	46.8	36.8	3.8	5.8	11.1	46.5	B.
	41.8	36.2	3.5	5.4	10.5	47.7	B.
	43.1	34.7	3.5	5.0	9.8	33.0	B.
	43.9	36.7	3.2	5.0	10.2	35.8	B.
	42.7	35.8	3.2	5.0	9.8	63.1	B.

<i>Cardwellia sublimis</i>	Silky Oak	38.4	31.8	1.8	2.7	11.8	82.0	Q.
		36.1	30.6	4.7	7.3	9.6	98.3	Q.
<i>Cedrela Toona</i>	Cedar	26.1	22.8	3.1	5.0	7.1	110.1	B.
<i>Ceratopetalum apetalum</i>	Coachwood	42.3	31.7	6.2	8.9	21.3	111.6	Q.
		39.8	32.4	3.9	4.5	14.0	73.8	Q.
		35.2	27.6	5.9	10.6	16.4	106.1	B.
		41.5	34.2	8.9	12.3	19.6	103.9	B.
<i>Cryptocarya glaucescens</i>	Brown Beech	37.6	32.4	2.0	3.6	11.3	54.5	Q.
		29.0	26.4	2.2	2.9	10.3	125.3	Q.
		29.8	22.2	5.6	6.6	9.5	151.9	B.
		37.8	31.7	3.8	5.5	13.0	57.5	O.
<i>Cryptocarya erythroxylon</i>	Pigeon-berry Ash	42.5	34.2	5.4	7.5	12.5	52.5	B.
<i>Doryphora sassafras</i>	Sassafras	39.3	32.4	3.0	5.5	19.5	66.8	Q.
		31.6	25.9	2.6	4.3	17.0	132.9	Q.
		35.5	29.4	2.4	4.5	17.0	106.0	Q.
		33.3	26.4	7.7	11.9	15.2	135.3	B.
		41.1	32.4	8.9	10.2	15.7	104.0	B.
		30.3	25.0	7.0	10.4	14.4	151.8	B.
		39.1	32.4	6.7	9.3	16.9	52.0	B.
		41.3	32.6	8.8	13.1	18.8	101.0	B.
		35.4	29.9	6.8	10.5	15.3	62.0	B.



AUSTRALIAN TIMBERS (*continued*).

	1	2	3	4	5	6	7
<i>Dysoxylum Fraserianum</i>							
Rosewood	45.9	37.8	1.8	4.8	10.2	82.0	Q.
	45.8	39.0	2.0	5.6	14.7	93.5	Q.
	47.9	40.8	2.7	6.6	15.5	90.1	Q.
	42.3	36.6	1.5	3.7	10.3	107.0	Q.
	47.9	40.6	4.6	8.4	13.9	63.8	B.
	41.1	35.5	3.7	7.1	11.6	111.8	B.
	45.1	36.0	3.9	6.0	11.4	86.0	B.
	47.6	40.1	4.3	8.2	14.9	91.4	B.
<i>Endiandra Sieberi</i>	52.1	42.6	6.8	7.7	16.0	53.0	B.
	52.4	43.5	6.9	9.6	15.7	43.0	B.
<i>Eucalyptus Andrewsii</i>	52.6	40.6	6.1	8.1	23.0	78.3	Q.
New England Peppermint	56.0	41.2	9.1	11.1	25.5	77.1	B.
	56.3	44.6	7.4	10.9	16.5	67.5	B.
	62.4	48.0	7.7	10.1	18.2	44.0	O.
<i>Euc. globulus (E. bicostata)</i>	56.6	44.6	5.0	6.8	17.7	61.8	Q.
Eurabbie	60.3	44.2	11.8	13.4	22.0	62.0	B.
<i>Euc. botryoides</i>	58.5	43.2	6.9	10.1	26.5	63.5	Q.
Bangalay	61.2	44.5	11.2	13.6	24.2	64.2	B.

<i>Euc. crebra</i>	Narrow-leaved Ironbark	67.9	55.1	4.8	7.1	14.5	34.9	Q.
		66.0	55.1	6.1	9.4	16.5	37.5	B.
<i>Euc. Dalrympleana</i>	Mountain Gum	48.8	36.4	6.1	9.5	26.7	84.7	Q.
		47.9	36.7	9.7	12.9	25.0	85.5	B.
<i>Euc. Delegatensis</i>	Alpine Ash	40.4	31.5	5.4	7.7	25.2	115.8	Q.
		41.1	31.8	7.3	11.1	20.1	103.9	B.
<i>Euc. eugenioides</i>	White Stringybark	53.6	43.5	6.4	9.3	16.8	69.0	O.
		51.6	45.6	6.0	8.7	13.7	67.5	B.
<i>Euc. fastigata</i>	Brown Barrel	57.4	42.5	6.0	8.5	21.0	75.4	Q.
		57.6	42.5	10.1	11.5	20.0	64.4	B.
<i>Euc. macrorrhyncha</i>	Red Stringybark	48.9	39.2	3.6	7.2	18.5	70.4	Q.
		50.7	39.8	4.7	9.8	17.0	63.0	Q.
		49.9	39.4	7.3	9.8	19.0	67.5	B.
		50.6	39.4	6.0	9.0	16.5	66.7	B.
<i>Euc. maculata</i>	Spotted Gum	58.1	42.2	5.3	7.7	15.9	49.0	Q.
		44.6	37.8	4.5	9.1	19.5	86.7	Q.
		60.3	—	5.2	—	—	39.2	Q.
		58.9	50.7	8.0	11.0	18.7	44.7	B.
		55.1	44.3	6.6	10.5	18.1	52.0	B.
		56.7	46.7	8.0	9.3	15.5	49.9	B.

AUSTRALIAN TIMBERS (*continued*).

	1	2	3	4	5	6	7
<i>Euc. microcorys</i>							
Tallowwood	57.0	—	2.8	—	—	58.0	Q.
	56.7	—	2.8	—	—	58.0	Q.
	57.4	—	2.8	—	—	58.0	Q.
	59.3	47.4	5.4	8.0	16.5	58.3	O.
	58.9	48.1	5.1	8.0	16.8	63.0	O.
	58.9	48.4	3.3	4.8	15.0	47.8	Q.
	61.9	50.7	3.5	5.1	16.5	57.2	Q.
	61.9	50.9	5.7	8.0	17.2	50.8	O.
	63.6	51.4	4.2	5.9	15.1	51.8	O.
	64.4	51.6	6.9	9.6	15.9	35.8	B.
	62.1	51.0	4.8	7.7	13.2	44.6	B.
	64.6	54.1	6.2	9.2	15.7	51.4	B.
	62.3	50.5	6.6	10.0	19.0	51.0	B.
	62.4	48.7	8.0	10.1	16.9	53.2	B.
	60.7	48.9	7.3	10.1	17.3	58.5	B.
<i>Euc. oreades</i>	46.5	33.5	10.7	15.5	27.5	95.0	B.
Mountain Ash	47.0	35.8	10.7	12.2	20.0	87.7	B.
<i>Euc. obliqua</i>	52.4	43.0	8.3	10.3	21.4	66.5	O.
	54.4	41.0	8.9	11.3	22.4	69.8	B.
<i>Euc. phellandra</i>	43.1	35.1	3.0	5.6	20.0	88.2	Q.
( <i>E. Robertsoni</i> )	43.7	35.1	7.1	12.5	18.1	87.7	B.
<i>Euc. pilularis</i>	60.9	47.9	4.3	6.5	18.0	40.7	Q.
Blackbutt	57.7	45.1	5.7	9.0	20.5	51.7	Q.
	50.5	40.7	5.7	6.7	18.0	47.7	O.

<i>E. piperita</i>	Peppermint	57.0	48.4	2.8	5.5	9.5	19.4	B.
		61.9	48.9	6.4	11.0	16.9	53.7	B.
		59.6	47.3	7.4	10.9	17.0	40.0	B.
		60.2	47.3	9.8	11.7	18.0	65.0	B.
		60.6	47.4	9.5	12.0	18.8	62.8	B.
<i>Euc. polyanthemoides</i>	Red Box	68.0	55.8	3.9	5.3	13.1	40.2	Q.
		67.5	55.5	5.4	7.4	13.8	40.0	B.
<i>Euc. punctata</i>	Grey Gum	67.4	55.0	4.8	5.6	14.9	43.3	Q.
		69.0	55.7	6.1	7.1	14.0	35.2	B.
		69.5	56.1	5.3	6.5	11.9	35.9	B.
		69.5	—	5.2	—	—	30.5	B.
<i>Euc. rariflora</i>	Black Box	74.2	61.0	6.2	8.3	13.5	36.3	B.
		74.5	59.8	5.7	7.4	14.7	36.8	B.
		73.2	57.5	5.9	7.7	14.3	36.7	B.
		73.1	58.5	6.0	7.0	15.2	39.6	B.
		64.8	50.7	6.7	8.2	18.3	34.2	Q.
		63.7	51.6	5.1	6.5	13.0	32.4	Q.
		57.7	46.8	4.8	9.4	19.1	41.0	Q.
		59.9	48.4	4.9	8.0	18.2	49.4	Q.
		65.6	52.5	6.2	8.5	20.3	42.4	Q.
		53.5	44.5	3.4	5.8	13.3	58.2	Q.
		54.9	45.5	6.9	9.2	15.0	62.8	B.
		61.4	49.5	6.8	7.6	14.8	53.7	B.
		62.5	49.8	6.9	10.9	21.5	39.0	B.
		58.1	48.6	5.9	9.6	18.8	41.1	B.
<i>Euc. resinifera</i>	Red Mahogany	66.0	54.1	5.6	8.6	15.5	30.0	B.

AUSTRALIAN TIMBERS (*continued*).

	1	2	3	4	5	6	7
<i>Euc. rostrata</i>							
Murray Red Gum	57.0	44.9	3.8	6.2	15.4	58.0	Q.
	56.9	44.4	4.7	6.2	15.9	59.8	Q.
	54.7	42.5	7.7	7.7	15.0	70.3	O.
	57.2	42.6	9.6	10.9	22.5	51.1	B.
<i>Euc. saligna</i>							
Blue Gum	47.9	39.4	5.2	10.5	16.8	70.6	B.
	58.3	46.3	5.5	7.8	19.6	45.6	Q.
	57.6	46.0	5.0	7.1	20.0	54.5	Q.
	55.6	38.4	5.9	11.4	29.5	60.4	Q.
	56.9	46.5	4.8	8.1	20.8	42.2	Q.
	65.1	—	7.6	—	—	43.1	O.
	60.6	47.9	6.5	8.8	19.3	44.4	Q.
	62.5	—	5.8	—	—	33.7	B.
	49.6	39.3	6.3	10.9	19.1	54.5	B.
	57.1	43.8	12.6	15.3	22.5	63.7	B.
	59.7	46.3	7.9	11.5	18.0	51.5	B.
<i>Euc. sideroxylon</i>							
Red Ironbark	65.5	55.6	3.4	5.3	13.4	43.7	Q.
	65.0	53.0	6.0	7.8	12.3	37.5	B.
<i>Euc. tereticornis</i>							
Red Gum	64.3	52.5	5.4	7.6	15.0	54.5	O.
	64.3	52.9	6.3	11.5	15.3	51.3	B.
<i>Euc. viminalis</i>							
Ribbon Gum	50.7	39.8	6.4	9.1	22.3	77.4	Q.
	60.4	43.3	12.8	13.8	21.1	72.7	Q.
<i>Flindersia Brayleyana</i>							
Queensland Maple	38.5	31.0	3.8	5.4	15.6	23.0	Q.
	34.0	27.3	3.7	5.7	15.3	66.7	Q.
	35.0	29.2	6.0	8.2	13.5	97.7	B.

<i>Blindsia australis</i>	Colonial Teak	57.5	46.7	5.7	8.5	20.1	28.8	B.
<i>Geissois Benthami</i>	Red Carabeen	38.7	31.9	3.2	4.8	14.7	82.3	Q.
		39.3	31.1	7.6	0.2	16.1	82.8	B.
<i>Gmelina Leichhardtii</i>	Beech	33.8	30.2	1.1	4.5	10.3	130.0	Q.
		34.0	30.0	1.2	4.4	9.9	129.0	Q.
		32.2	27.2	5.4	6.3	8.7	97.6	B.
		33.0	28.8	6.0	7.5	7.0	113.8	B.
		36.8	32.4	3.8	3.2	7.5	75.8	B.
<i>Litsea reticulata</i>	Bolly Gum	28.7	24.2	4.5	5.5	10.0	109.0	B.
<i>Orites excelsa</i>	Prickly Ash	41.9	33.8	2.4	3.7	15.8	95.4	Q.
	Silky Oak	40.9	34.6	7.1	0.2	14.8	105.4	B.
<i>Pittosporum undulatum</i>	White Holly	51.6	40.5	9.8	1.1	15.7	72.2	B.
<i>Schizomeria ovata</i>	Crab Apple	48.2	37.8	3.3	8.5	16.3	71.1	Q.
		47.9	40.4	9.6	8.5	16.0	74.0	B.
		42.0	34.4	2.8	3.9	13.2	60.5	Q.
<i>Sloanea Woollsii</i>	Yellow Carabeen	40.5	32.6	6.3	8.3	11.7	58.7	B.
		52.0	48.4	2.1	4.4	16.3	67.5	Q.
<i>Stenocarpus salignus</i>	Beefwood	52.3	44.9	2.5	5.9	17.1	68.4	Q.
		65.2	55.4	5.8	7.8	22.5	62.8	Q.
<i>Syncarpia laurifolia</i>	Turpentine	59.2	42.7	6.4	8.6	21.3	75.1	Q.
		59.2	42.5	6.7	8.4	24.1	73.7	Q.
		58.1	43.2	12.4	4.5	24.2	69.3	B.
		64.5	55.4	11.1	2.9	20.6	55.4	B.
<i>Tarrietia actinophylla</i>	Stavewood	55.1	42.9	5.4	7.3	20.1	59.5	Q.
		49.8	39.6	9.4	1.4	16.4	60.4	B.

AUSTRALIAN TIMBERS (*continued*).

	1	2	3	4	5	6	7
<i>Tarrietia argyrodendron</i>	52.0	39.1	6.1	7.1	13.5	88.0	O.
Crow's-foot Elm	49.9	40.2	5.3	6.7	11.3	44.4	O.
<i>Tristania conferta</i>	44.5	40.9	4.0	5.8	17.3	80.5	Q.
Brush Box	56.1	44.1	3.5	5.4	18.7	70.4	Q.
	49.7	39.5	6.4	8.8	14.0	73.3	B.
	53.0	41.8	8.1	12.3	22.8	69.7	B.
	53.6	45.5	9.2	8.6	15.7	67.7	B.
	55.4	43.6	8.6	9.4	14.7	67.9	B.
<i>Xanthophyllum Macintyrii</i>	49.9	42.3	7.3	9.4	14.4	64.1	B.
Sovereign Wood							

## NON-AUSTRALIAN TIMBERS.

	1	2	3	4	5	6	7
<i>Acacia</i> sp.	34.6	28.8	2.3	2.9	10.7	127.4	Q.
Noumean Blackwood	47.8	34.2	4.4	4.5	11.4	77.9	B.
<i>Agathis lanceolata</i>	35.7	29.5	2.9	4.3	11.4	36.7	Q.
	34.9	—	3.9	—	—	65.8	B.
<i>Azadirachta integrifolia</i>	32.3	27.0	1.8	3.3	8.3	20.4	Q.*
<i>Calophyllum</i> sp.	37.4	—	3.8	—	—	57.3	Q.
	39.5	—	5.9	—	—	60.3	B.
<i>Quercus crispula</i>	43.9	35.4	3.4	4.4	16.6	77.0	Q.
Japanese Oak							

Shorea sp.	Pacific Maple										
	26.4	24.6	2.3	4.3	13.5	85.4	Q.				
	29.5	24.9	2.0	3.7	11.3	66.4	Q.				
	30.5	25.5	2.1	3.9	11.2	60.5	Q.				
	32.4	27.6	2.6	3.9	9.8	51.5	Q.				
	30.2	24.9	3.2	5.2	12.7	61.8	O.				
	25.4	22.0	5.3	8.0	12.1	61.2	B.				
	33.9	28.3	4.1	7.3	11.0	51.2	B.				
	31.8	26.6	5.4	9.5	12.6	72.2	B.				
	34.8	29.5	4.3	6.2	9.6	53.1	B.				
	34.4	29.2	3.5	5.6	9.3	57.5	B.				
	28.8	24.4	1.6	3.2	9.2	95.8	Q.				
	31.2	25.8	4.3	6.1	10.3	89.3	B.				
Terminalia gigantea	Solisle Oak										

\* These samples have too low a moisture content to be regarded as "green."

1 = Weight per cubic foot; air dry volume and weight.

2 = Weight per cubic foot; green volume, oven dry weight.

3 = Lateral shrinkage %—green to air dry.

4 = Lateral shrinkage %—green to oven dry.

5 = Volumetric shrinkage green to oven dry.

6 = Moisture % on dry weight.

7 = Direction of cut, Q. = Quarter or radially cut, i.e., parallel to rays.

B. = Backed off or tangentially cut, i.e., at right angles to rays.

O. = Oblique, i.e., at approximately 45° to rays.

A tolerance of 15° was permitted.



The figures given in the table are self explanatory and little comment is necessary.

Certain timbers stand out as possessing a small amount of radial shrinkage, thus Beech 1.1-1.2, Blackwood 1.4-1.9, Rosewood 1.5-2.7, Silky Oak (*Cardwellia*) 1.8, Brown Beech (*Cryptocarya*) 2.0-2.2, Beefwood 2.1-2.5 are the best examples of this. Although the shrinkage of Beech is usually regarded as negligible, this is probably due to the abnormally slow loss of moisture from this wood, since the tangential shrinkage varied from 3.8 to 6.0%, i.e., about five times the radial shrinkage. Another unusual feature of this wood is the high radial shrinkage from green to oven dry, namely, 4.5% ; in most woods the ratio of oven dry to air dry shrinkage is well below 2.

In some woods the ratio of tangential and radial shrinkage is low, e.g., in Cypress Pine the mean figures are 3.5 to 2.7 respectively. Rosewood also possesses a low tangential shrinkage which no doubt accounts for the fact that this wood can be used for turnery in a practically unseasoned condition.

Woods which possess a marked difference between the radial and tangential shrinkage are most liable to warp and cup, especially when cut obliquely or backed off, and this is seen in the case of Sassafras, where the radial shrinkage is 2.7% and the tangential shrinkage 7.7%.

High figures for tangential shrinkages of about 12% were found in Turpentine and in several Eucalypts: such figures were in most cases due to collapse.

There is not sufficient data to enable any comparisons to be made between density and shrinkage.

In conclusion, acknowledgment is due to the Forestry Commission, Sydney, and many others, for the timber samples used, and especially to Mr. F. B. Shambler, of the Technological Museum Staff, for his very able assistance during the progress of the work.

# ABSTRACT OF PROCEEDINGS

OF THE

## Royal Society of New South Wales.



MAY 6TH, 1931.

The Annual Meeting, being the five hundredth General Monthly Meeting of the Society, was held in the Hall of Science House, Gloucester and Essex Streets, Sydney, at 8 p.m.

Professor O. U. Vonwiller, President, in the Chair.

Seventy members and thirty visitors were present.

The reading of the General Monthly Minutes of 3rd December, 1930, was deferred to the next meeting.

The President reported that this was the first meeting in Science House, and that the Official Opening would take place on the following afternoon, when His Excellency Air Vice-Marshal Sir Philip Woolcott Game, G.B.E., K.C.B., D.S.O., would formally open the building. This would be followed by an exhibition held on all floors of the building, which would include exhibits illustrating science, engineering, architecture, surveying, astronomy, etc. This exhibition would remain open until the following Saturday mid-day.

The certificates of the following candidates were read for the first time: Warnford Moppett, biologist, Cancer Research Department, University of Sydney, and Jack Maxwell Rayner, physicist to the Department of Mines, New South Wales.

The Annual Financial Statement for the year ending 31st March, 1931, was submitted to members, and on the motion of Professor H. G. Chapman, seconded by Mr. C. A. Sussmilch, was unanimously adopted.

# ROYAL SOCIETY OF NEW SOUTH WALES.

## Statement of Receipts and Payments for the year ended 31st March, 1931.

### GENERAL ACCOUNT.

#### RECEIPTS.

	£	s.	d.	£	s.	d.
To Balance—31st March, 1930 .. ...				1186	8	0
„ Revenue —						
Subscriptions .. ...	464	2	0			
Rents ... ..	207	12	2			
Sundry Receipts ... ..	23	6	2			
Government Subsidy . ...	100	0	0			
Interest—						
Government Bonds & Stock ... ..						
and Loan... ..	1140	1	2			
				1935	1	6
„ Liversidge Bequest—Interest ... ..				3	0	3
„ Royal Society's Fund—Interest added ...				299	7	3
„ Loan ... ..				20000	0	0
				<u>£23423</u>	<u>17</u>	<u>0</u>

#### PAYMENTS.

	£	s.	d.	£	s.	d.
By Administrative Expenses—						
Salaries and Wages—						
Office Salary and Accountancy						
Fees ... ..	291	15	0			
Assistant Librarian ... ..	48	0	0			
Caretaker ... ..	202	10	0			
				542	5	0
Printing, Stationery, Advertising and Stamps—						
Stamps and Telegrams ... ..	31	6	6			
Office Sundries and Stationery ...	7	0	8			
Advertising ... ..	4	12	0			
Printing ... ..	67	4	3			
				110	3	5

Rent, Rates, Taxes and Services—					£	s.	d.	£	s.	d.
Rent	...	...	...	...	481	4	8			
Electric Light and Gas	...	...	...	...	36	12	4			
Insurance	...	.	...	...	21	11	9			
Telephone	...	...	...	...	18	15	2			
					—558 3 11					
Printing and Publishing Society's										
Volume—										
Printing, &c.	...	...	...	...	188	7	3			
Bookbinding	...	...	...	...	46	13	9			
					—235 1 0					
Library—										
Bookbinding	...	...	...	...				266	14	3
Sundry Expenses—										
Removal Expenses	...	...	...	...	17	4	0			
Repairs	...	...	...	...	23	12	2			
Lift Attendant	...	...	...	...	47	5	0			
Bank Charges	...	..	...	...	4	12	0			
Sundries	...	...	...	...	51	8	2			
					—144 1 4					
					—1856 8 11					
„ Interest—										
Union Bank of Australia Ltd.								0	11	6
Royal Society's Fund ...								299	7	3
Loan Fund								135	14	11
					—435 13 8					
„ Furniture								402	2	6
„ Science House								12606	13	10
„ J. H. Maiden Memorial Fund								1	1	0
„ Loan on Mortgage—Institution										
of Engineers								4950	0	0
„ Government Bonds and Stocks								1176	5	0
„ Clarke Memorial Fund								11	6	
„ Building Investment Loan Fund								1080	0	0
„ Balance--31st March, 1931,										
Union Bank of Australia Ltd.								915	0	7
					—					
					£23423 17 0					

Compiled from the Books and Accounts of the Royal Society of New South Wales, and certified to be in accordance therewith.

(Sgd.) HENRY G. CHAPMAN, M.D., *Honorary Treasurer.*

(Sgd.) W. PERCIVAL MINELL, F.C.A. (Aust.), *Auditor.*

SYDNEY, 28TH APRIL, 1931.

## BALANCE SHEET AS AT 31st MARCH, 1931.

LIABILITIES.				£	s.	d.	£	s.	d.
Investment Fund—									
Clarke Memorial Fund				1374	1	0			
Walter Burfitt Prize Fund	...	...		593	15	9			
Investment Fund...	...	..	...	3757	13	3			
Liversidge Bequest	...	...	...	565	5	2			
							6290	15	2
On Loan	...	...	...				2320	0	0
Sundry Liabilities	...	...	...				231	8	0
Accumulated Funds	...	..	...				29109	13	10
							£37951	17	0
ASSETS.									
Cash—									
Union Bank of Australia, Ltd.	...						915	0	7
Government Bonds and Stock (Nominal Value £7350)	...	...					7073	7	5
Science House Management Committee—									
Payments to date	...	...	...				13270	0	0
Sundry Debtors—									
Institution of Engineers...	...	...	...	4950	0	0			
For Rents and Sundries	...	...	...	40	10	4			
For Subscriptions in arrears	...	...	...	528	11	0			
							5519	1	4
Library—									
Insurance Valuation	...	...	...	9115	10	11			
Add:—Expenditure during year	...		...	266	14	3			
							9382	5	2
Office Furniture—Insurance Valuation	...						1452	2	6
Pictures—Insurance Valuation	...	...					180	0	0
Microscopes—Insurance Valuation	...	...					120	0	0
Lantern—Insurance Valuation	...	...					40	0	0
							£37951	17	0

Compiled from the Books and Accounts of The Royal Society of New South Wales, and certified to be in accordance therewith.

(Sgd.) HENRY G. CHAPMAN, M.D., Honorary Treasurer.

(Sgd.) W. PERCIVAL MINELL, F.C.A. (Aust.), Auditor.

Queensland National Bank Chambers,

27 Hunter Street, Sydney, 28th April, 1931.

**INVESTMENT FUND.**

**STATEMENT OF RECEIPTS AND PAYMENTS FOR THE  
YEAR ENDED 31st MARCH, 1931.**

## RECEIPTS.

				£	s.	d.	£	s.	d.
To Balance—31st March, 1930	...	...	...				5988	19	2
„ Interest—									
Clarke Memorial Fund	...	...	...	65	9	0			
Walter Burfitt Prize Fund	...	...	...	28	5	0			
Liversidge Bequest	...	...	...	29	15	6			
Investment Fund	...	...	...	178	18	0			
							302	7	6
							£6291	6	8

### PAYMENTS.

						£	s.	d.
By Expenditure—Clarke Memorial Fund	...	...	...	...	...	11	6	
„ Balance—31st March, 1931	...	...	...	...	...	6290	15	2
						£6291	6	8

On the motion of Mr. C. A. Sussmitch, seconded by Professor R. D. Watt, Mr. W. P. Minell was duly elected Auditor for the coming year.

The Annual Report of the Council was read, and on the motion of Mr. C. A. Sussmilch, seconded by Mr. A. E. Stephen, was adopted.

## REPORT OF THE COUNCIL FOR THE YEAR 1930-31.

(1st May to 29th April.)

The Council regrets to report the loss by death of four ordinary members and two honorary members. Twenty-one members have resigned. On the other hand, eight ordinary members and one honorary member have been elected during the year. To-day (29th April, 1931), the roll of members stands at 307.

During the Society's year, there have been eight general monthly and ten council meetings.

Four Popular Science Lectures were given, namely:—  
July 17—"The Romance of Wood," by M. B. Welch,  
B.Sc., A.I.C.

August 21—"Natural History Museums," by C. Anderson,  
M.A., D.Sc.

September 18—"The Developments in Economic Importance of Carbon Compounds," by V. M. Trikojus,  
B.Sc., D.Phil.

October 16—"Wool Fibre; its Nature, Character and Use,"  
by Professor J. Douglas Stewart, B.V.Sc., M.R.C.V.S.

Meetings were held throughout the Session by the Sections of Geology and Physical Science.

The Section of Industry during the year again devoted its attention to visiting industrial establishments.

Special invitations were extended to members on the following dates: Thursday, 3rd July, 1930, Amalgamated Wireless Works at Knox Street, and the Wireless Transmitting Station at Radio Centre, Pennant Hills, and on Thursday, 16th October, 1930, to the H.M.S. "Oxley."

Eighteen papers were read at the General Monthly Meetings, and covered a wide range of subjects.

Lecturettes were given at the monthly meetings in June, July, August, September, October, November and December, by Messrs. A. R. Penfold, O. U. Vonwiller, C. A. Sussmilch, Warnford Moppett, A. R. Radcliffe-Brown, A. S. LeSouef and D. T. Sawkins, respectively.

On Thursday afternoon, 14th November, 1930, a special lecture was delivered to members of the Royal Society by Professor A. S. Mitchell of the Leander McCormick Observatory, Virginia, U.S.A., on "The Recent Eclipse."

*Maiden Memorial Pavilion:* The Maiden Memorial Pavilion was officially opened by the Lieutenant-Governor, Sir William Cullen, on Monday, 19th May, 1930.

*Science House:* The foundation stone of Science House was set by His Excellency Air Vice-Marshal Sir Philip Woolcott Game, G.B.E., K.C.B., D.S.O., Governor of New South Wales, on Tuesday, 24th June, 1930, and on the 15th January, 1931, the Royal Society of New South Wales took possession of its part of the building.

The Annual Dinner took place at the University Club, Phillip Street, Sydney, on Thursday, 23rd April (St. George's Day), 1931, when we were honoured by the presence of His Excellency Sir Philip Game, Mr. S. G. Thorp (Architect for Science House), and the presidents of the Linnean Society of New South Wales, the Institution of Engineers, Australia, and the Chamber of Manufactures.

The Council has awarded the Clarke Memorial Medal to Robin John Tillyard, M.A., D.Sc., F.R.S., F.L.S., F.E.S.

The donations to the library have been as follow: 39 volumes, 1524 parts, 29 reports, 6 maps, 1 catalogue and 6 calendars.

*Government Subsidy:* On the 14th August, 1930, the Society was notified by the Director for Education that the government subsidy, which for many years past had been £400 per annum, would be reduced to £200 per annum.

It was announced that the Council had awarded the Clarke Memorial Medal to Dr. R. J. Tillyard, F.R.S., and the President then made the presentation. Dr. Tillyard expressed his appreciation of the Council's action in making the award.

The President announced that the following popular science lectures would be delivered this session:—



July 16—"Oysters and Oyster Culture," by T. C. Roughley.

August 20—"The Oceanographical Work of the 'S.Y. Discovery' in the Antarctic Seas," by W. W. Ingram, M.C., M.D., Ch.B.

September 17—"The Sun," by Rev. Wm. O'Leary, S.J.

October 15—"Insect Life," by W. B. Gurney, B.Sc.

A letter was read from the Consul-General for Denmark forwarding the "Dana Medal," symbolizing the circumnavigation of the Globe by the "Dana."

The following donations were received: 513 parts, 10 volumes, 5 reports, 1 calendar, and 1 catalogue.

The President, Professor O. U. Vonwiller, then delivered his address.

There being no other nominations, the President declared the following gentlemen to be officers and council for the coming year:

**President:**

EDWIN CHEEL.

**Vice-Presidents:**

Prof. R. D. WATT, M.A., B.Sc. Prof. L. A. COTTON, M.A., D.Sc.  
 Prof. J. DOUGLAS STEWART, Prof. O. U. VONWILLER,  
 B.V.Sc., M.R.C.V.S. B.Sc., F.Inst.P.

**Hon. Treasurer:**

Prof. H. G. CHAPMAN, M.D.

**Hon. Secretaries:**

C. A. SUSSMILCH, F.G.S. R. J. NOBLE, M.Sc., B.Sc.Agr.,  
 Ph.D.

**Members of Council:**

C. ANDERSON, M.A., D.Sc. Prof. C. E. FAWSITT, D.Sc.,  
 Ph.D.  
 E. C. ANDREWS, B.A., F.G.S. JAMES NANGLE, O.B.E.,  
 F.R.A.S.

**Assist.-Prof. W. R. BROWNE, Prof. T. G. B. OSBORN,**  
D.Sc. D.Sc., F.L.S.  
**R. W. CHALLINOR, F.I.C., A. R. PENFOLD, F.A.C.I.,**  
F.C.S. F.C.S.  
**Prof. J. C. EARL, D.Sc., Ph.D. M. B. WELCH, B.Sc., A.I.C.**

Professor Vonwiller, the out-going President, then installed Mr. Edwin Cheel as President for the coming year, and the latter briefly returned thanks.

On the motion of Professor Fawsitt, a hearty vote of thanks was accorded to the retiring president for his valuable address.

Professor Vonwiller briefly acknowledged the compliment.

#### JUNE, 3RD, 1931.

The five hundred and first General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 8 p.m.

Dr. C. Anderson in the Chair.

Thirty-five members and two visitors were present.

The Minutes of the General Monthly Meeting of 3rd December, 1930, and of the Annual Meeting of 6th May, 1931, were read and confirmed

The President nominated Mr. R. W. Challinor to preside at the Ballot Box, and members elected Messrs. H. V. Bettley-Cooke and H. G. Pyke to act as Scrutineers when the following gentlemen whose certificates had been read a second time were duly elected ordinary members of the Society: Warnford Moppett and Jack Maxwell Rayner; Thomas Ranken Lyle, K.B., C.B.E., D.Sc., F.R.S., was elected an honorary member of the Society.

The following donations were received: 409 parts, 8 volumes, 7 reports and 1 calendar.

A letter was read from the Secretary of the Old Boys' Union of the Hawkesbury Agricultural College, Richmond, in regard to a proposed memorial to the late Mr. H. W. Potts, who was Principal of the College for nineteen years.

Mr. A. B. Hector gave notice that at the next meeting he would move:—

“That in view of the confusion which exists between the meaning of the ‘Logical Method’ and the ‘Technological Method’ of investigating phenomena, that equal honour and consideration be given to both methods.”

THE FOLLOWING PAPERS WERE READ

1.—“A new Colorimetric Method for measuring the Hydrogen Ion Concentration of Natural Waters,” by Daphne Goulston (communicated by Prof. H. G. Chapman).

2.—“The Splenectomy of Tadpoles,” by Daphne Goulston (communicated by Prof. H. G. Chapman).

3.—“Variations of the Hydrogen Ion Concentration of Sea Water,” by Daphne Goulston (communicated by Prof. H. G. Chapman).

4.—“On the Metabolism of Cold-Blooded Animals,” by Daphne Goulston (communicated by Prof. H. G. Chapman).

5.—“The Mineralogy and Origin of the Natural Beach Sand Concentrates of New South Wales,” by H. F. Whitworth, B.Sc. (communicated by C. A. Sussmilch).

Remarks were made by Dr. W. R. Browne, Messrs. A. R. Penfold, and H. G. Raggat.

6.—“The Celluloses of Two Water Plants,” by Prof. John Campbell Earl, D.Sc., Ph.D., and Miss Thelma M. Reynolds, M.Sc.

LECTURETTE

“The Effect of Radium upon Eggs,” by Prof. H. G. Chapman, illustrated by lantern slides.

JULY 1st, 1931.

The five hundred and second General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 8 p.m.

Mr. E. Cheel, President, in the Chair.

Forty members and twelve visitors were present.

The Minutes of the preceding meeting were read and confirmed.

The certificate of the following candidate was read for the first time: Frederick William Wheatley, Director of Cranbrook School, Edgecliff.

The President announced that a popular science lecture, entitled "Oysters and Oyster Culture," would be delivered by Mr. T. C. Roughley on Thursday, 16th July, 1931, at 8 p.m.

It was also announced that the First Liversidge Research Lecture would be delivered before the Royal Society by Mr. Harry Hey, Chief Metallurgist of the Electrolytic Zinc Company of Australasia Ltd., Melbourne, in the Hall of Science House, on Thursday, 24th September, 1931, at 8 p.m.

An invitation was received from the Town Clerk of North Sydney, inviting members to the ceremony of planting trees in the new reserve at Ball's Head, on Saturday, 25th July, 1931, at 2 p.m.

The President, on behalf of the Council, gave notice of the following Motion, to be submitted at the next General Meeting:—

Rule 9.—The annual subscription shall be £2/2/-, payable in advance, but members elected prior to December, 1879, shall be required to pay an annual subscription of £1/1/- only as heretofore.

This ruling to be amended as follows:—

The annual subscription shall be £2/2/-, payable in advance but members who are under 28 years of age and those elected prior to December, 1879, shall be required to pay only £1/1/- yearly.

The following donations were received: 64 parts.

## THE FOLLOWING PAPER WAS READ

"Physiography of the Bathurst District," by C. A. Sussmilch, F.G.S.

Remarks were made by Messrs. E. C. Andrews, W. R. Browne, L. A. Cotton, J. MacDonald Holmes, H. G. Raggatt, and O. U. Vonwiller.

## LECTURETTE

"Modern Chemical Views on the Structure of Substances," by Prof. C. E. Fawsitt, Ph.D. (Illustrated by lantern slides.)

## AUGUST 5TH, 1931.

The five hundred and third General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 8 p.m.

Mr. E. Cheel, President, in the Chair.

Thirty members and ten visitors were present.

The Minutes of the preceding meeting were read and confirmed.

The President announced the death of Mr. David Reid, who had been elected a member in 1914.

A letter was read from the Misses Reid, expressing their appreciation of the Society's sympathy in their recent bereavement.

The President nominated Mr. M. B. Welch to preside at the Ballot Box, and members elected Dr. G. Harker and Mr. H. V. Bettley-Cooke to act as Scrutineers when the following gentleman, whose certificate had been read a second time, was duly elected an ordinary member of the Society: Frederick William Wheatley.

It was announced that a popular science lecture, entitled "The Oceanographical Work of the 'S.Y. Discovery' in the Antarctic Seas," would be delivered by Dr. W. W. Ingram, on Thursday, 20th August, 1931, at 8 p.m.

A letter was read from the Under-Secretary, Department of Agriculture, Sydney, stating that a scientific expedition is being despatched by the University of Harvard, Massachusetts, U.S.A., arriving in Sydney early in August for the purpose of gathering entomological, zoological and ornithological specimens for their Museum of Comparative Zoology. The personnel of the party being: Professor W. M. Wheeler, Mr. H. Stevens, Dr. Glover Allen, Dr. R. J. Darlington, Mr. W. E. Sheville, Dr. Ira Dixon and Mr. Ralph Ellis.

Mr. C. A. Susasmilch, on behalf of the Council, moved the alteration of Rule 9 of which notice had been given at the previous meeting, namely: That Rule 9 be altered to read as follows:—

“The annual subscription shall be Two Guineas, payable in advance, but members who are under twenty-eight years of age and those elected prior to December, 1879, shall be required to pay only One Guinea yearly.”

This was seconded by Mr. A. R. Penfold, and carried unanimously. The President announced that the Resolution would be submitted for confirmation at the next Annual Meeting.

#### THE FOLLOWING PAPERS WERE READ

1.—“On a specimen of Fossil Timber from the Sydney Harbour Colliery,” by R. T. Baker.

2.—“Notes on Bathyliths and some of their Implications,” by Assist.-Prof. W. R. Browne, D.Sc.

#### LECTURE:

“The Cultivation of the Tung Oil Tree (*Aleurites Fordii*) in Australia,” by A. R. Penfold, F.C.S.

#### EXHIBITS:

1.—“Journal Bearings made from Australian Hardwoods,” by E. G. Bishop.

2.—“Avertin,” by A. B. Hector.

## SEPTEMBER 2ND, 1931.

The five hundred and fourth General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 8 p.m.

Mr. E. Cheel, President, in the Chair.

Thirty-three members and one visitor were present.

The Minutes of the preceding meeting were read and confirmed.

The President announced the deaths of Messrs. Robert Grant, elected a member in 1922, and Sydney Harnett Stroud, elected in 1919.

It was announced that a popular science lecture, entitled "The Sun," would be delivered by the Rev. Wm. O'Leary, on Thursday, 17th September, 1931, at 8 p.m.

It was also announced that Commemorative Addresses in connection with the Centenary of Michael Faraday's "Discovery of Electro-Magnetic Induction" would be delivered by Professors J. P. V. Madsen and O. U. Vonwiller in the Great Hall of the University of Sydney on Tuesday, 22nd September, 1931, at 8.5 p.m.

The President also announced that the First Liversidge Research Lecture, entitled "The Production of Zinc by Electrolysis of Zinc Sulphate Solutions," would be delivered by Mr. Harry Hey on Thursday, 24th September, 1931, at 8 p.m.

The following donations were received: 7 volumes, 126 parts, 3 reports, and 1 calendar.

## THE FOLLOWING PAPERS WERE READ

1.—"The amount of Hydrocyanic Acid in Sorghum and some Hybrids," by H. Finnemore, B.Sc., and C. B. Cox, B.Sc.

Remarks were made by Mr. R. W. Challinor and Professor J. Douglas Stewart.

2.—“A contribution to the Chemistry of the Fruit obtained from the White Cedar Tree (*Melia Azedarach*, Var. *Australasica* D.DC.; Syn. *Melia Australasica*, A. Juss), growing in New South Wales, with notes on its reputed toxicity,” by F. R. Morrison, F.C.S., A.A.C.I., A.S.T.C., and R. Grant, F.C.S.

## LECTURETTE:

“Breeding for disease resistance in Plants” (illustrated by lantern slides), by W. L. Waterhouse, M.C., D.Sc.Agr., D.I.C.

## EXHIBIT:

“A note on Molecular Movement,” by Mr. A. B. Hector.

## OCTOBER 7TH, 1931.

The five hundred and fifth General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 8 p.m.

Mr. E. Cheel, President, in the Chair.

Thirty members were present.

The Minutes of the preceding meeting were read and confirmed.

Letters were read from Mesdames R. Grant and S. H. Stroud, expressing thanks for the Society's sympathy in their recent bereavements.

The President announced that a popular science lecture, entitled “Insect Life,” would be delivered by Mr. W. B. Gurney on Thursday, 15th October, 1931, at 8 p.m.

The following donations were received: 108 parts, 3 volumes, 6 reports, and 1 map.

The President reminded members that a “Walter Burfitt Prize” would be awarded during the year 1932 and that nominations should be received early next year.

The Hon. Secretary reported that the James Clerk Maxwell Centenary was being celebrated, during this month, in London, and that the Royal Society was being



represented at the celebration by Professor Kerr Grant, of South Australia, and Dr. W. H. Love, of Sydney.

THE FOLLOWING PAPER WAS READ:

"The condensation of  $\alpha\beta$ -Dibromocarboxylic acids with benzene in the presence of aluminium halides," by Prof. J. C. Earl, D.Sc., Ph.D., and C. H. Wilson.

#### THE SEVENTY-FIFTH ANNIVERSARY OF THE ROYAL SOCIETY OF NEW SOUTH WALES.

A series of addresses upon the early history and some of the more prominent early workers of the Society was given by the following gentlemen: Dr. H. G. Chapman, Sir Edgeworth David, Dr. J. A. Dick, Mr. James Nangle and Sir Henry Barraclough.

On the suggestion of Sir Edgeworth David, it was decided to send a letter of greeting to Mr. E. F. Pittman, one of the very old members, now resident in Victoria.

A vote of thanks to the several speakers was proposed by Professor Fawsitt and carried with acclamation.

#### NOVEMBER 4TH, 1931.

The five hundred and sixth General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 8 p.m.

Mr. E. Cheel, President, in the Chair.

Twenty members were present.

The Minutes of the preceding meeting were read and confirmed.

A letter was read from Mr. E. F. Pittman, thanking members for message of greeting.

The following donations were received: 189 parts, 6 volumes, and 4 reports.

## THE FOLLOWING PAPERS WERE READ.

1.—“The Essential Oil of *Leptospermum Liversidgei* var. B. and the occurrence of Isopulegol,” by A. R. Penfold, F.C.S.

Remarks were made by Professor Earl and Mr. Finne-  
more.

2.—“Notes on the *Pericalymma* section of the genus *Leptospermum* (with descriptions of three new species),” by E. Cheel.

Remarks were made by Mr. M. B. Welch.

## LECTURETTE:

“Recent New Zealand Earthquakes,” by C. A. Sussmilch,  
F.G.S.

## DECEMBER 2ND, 1931.

The five hundred and seventh General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 8 p.m.

Mr. E. Cheel, President, in the Chair.

Sixteen members were present.

The Minutes of the preceding meeting were read and confirmed.

The President announced the death of Mr. William Mogford Hamlet, who was elected a member in 1877, and was President in 1899 and 1908.

The certificate of the following candidate was read for the first time: Francis Goulder, A.S.T.C., A.A.C.I., Manager of the Ever-Ready Works, Marshall Street, Surry Hills, Sydney.

The following donations were received: 312 parts, 9 volumes, 9 reports, 1 map, and 4 calendars.

Alteration to Rules to provide for the admission of Corporate Members:—

Rule VIII a.—A Partnership, Firm or Company may be admitted to corporate membership of the Society.

Application for admission shall be made according to the prescribed form of certificate for ordinary membership signed by not less than three members.

Rule VIII b.—The election of such corporate members shall be in the manner set forth for the election of ordinary members as in Rule VIII.

Rule VIII c.—The subscription for corporate membership will be five guineas per annum.

Rule VIII d.—Corporate members may nominate some member of their Firm or Staff to represent them at the meetings of the Society. Such representative, however, will not be eligible to hold office or for election as a member of council. They shall have all other privileges of ordinary members.

Considerable discussion took place, and the following suggestions were made for submission to the Council:—

(a) Moved by Mr. Jacobs and seconded by Mr. Challinor, that Rule VIIId be modified to provide for such corporate membership be not used for advertising purposes.

(b) Moved by Professor Earl, and seconded by Mr. Penfold, that in the proposed Rule VIIId that the second sentence starting with “such representative” be eliminated and replaced by the words “Such representative to be approved by the Council.”

#### THE FOLLOWING PAPERS WERE READ

1.—“Notes on Wattle Barks,” Part III, by M. B. Welch, B.Sc., F. A. Coombs, F.C.S., and W. H. McGlynn.

Remarks were made by Messrs. A. D. Olle and E. Cheel.

2.—“An Undescribed Species of Wattle, *Acacia filicifolia*,” by E. Cheel, F.L.S., and M. B. Welch, B.Sc.

Remarks were made by Mr. M. B. Welch.

3.—“Notes on the Shrinkage of Wood,” by M. B. Welch, B.Sc.

Remarks were made by Mr. E. Cheel.

#### LECTURETTE

“The Story of Indigo,” by Prof. J. C. Earl (Illustrated with Lantern Slides).

At the conclusion, a vote of thanks was moved by Professor Fawsitt, and carried unanimously.

At the conclusion, the President wished all the members the Compliments of the Season.

ABSTRACT OF THE PROCEEDINGS  
OF THE  
GEOLOGICAL SECTION.

*Annual Meeting, April 17th, 1931.*

Mr. C. A. Sussmilch was in the Chair.

Eleven members and eight visitors were present.

Mr. C. A. Sussmilch was elected Chairman and Mr. H. G. Raggatt, Hon. Secretary for the year.

It was agreed that the night of meeting should be the third Friday of each month, and that the time of meeting should be 7.15 p.m. instead of 7.45 p.m.

LXHIBITS

1. By Mr. W. S. Dun—A suite of Carboniferous fossils from the head of Maule's Creek, 24 miles north-east from Boggabri, including corals of the lithostrotion type and a number of brachiopods, gasteropods, and crinoids.
2. By Professor W. R. Browne—(a) Graptolites from the Upper Ordovician slates to the south of Cooma, lying on the strike of the Cooma Schists. *Diplograptus bicornis* was recognised. (b) Micaceous hematite from a schistose porphyry occurring in veins oblique to the schistosity.
3. By Sir Edgeworth David on behalf of Mr. Tom Dibley—Fossil plants, including *Thinnfeldia narrabeenensis* from the Narrabeen Shales, north of Narrabeen.

4. By Professor Cotton—A large specimen of *Clepsydropsis* from the Parish of Taree.
5. By Miss Ida A. Brown—(a) Dyke rock from Narooma, containing very large phenocrysts of hornblende, labradorite and biotite. (b) Spherulites from a quartz porphyry near Eden, with banded chalcedony.

Mr. T. Hodge Smith gave an account of his geological observations while on a recent expedition to Central Australia.

The mesas of the Tarlton Range were described and mention made of the Jervois Range area. The latter range forms a striking escarpment, suggestive of faulting and flanks a plateau about 2000 feet above sea-level. The range consists of a typical Pre-Cambrian complex, resembling the Broken Hill area. A number of minerals were collected, including a very rare type, sphærocobaltine.

At Oorobbra gneissic granite is found associated with the schist series and in the Hart Range both schist and gneiss are intersected by basic and acid intrusives.

Sir Edgeworth David, Professor Browne and Mr. Kenny discussed the address, and Mr. T. Hodge-Smith replied to points raised in the discussion.

*May 15th, 1931.*

Mr. C. A. Sussmilch was in the Chair.

Ten members and nine visitors were present.

EXHIBITS:

1. By Mr. E. J. Kenny, which were described by Mr. W. S. Dun, as follows—(a) Tertiary forms from South Ita and Buckalow bores; *Trigonia semi-undulata*, *Magasella*, *Corbula*, *Pectunculus*, *Turritella*, 2 spp., and a number of sharks' teeth. (b) Cretaceous forms from Tiboburra, including *Modiola eyrensis*, *Maccoyella barklyi*, *Fissilunula clarkiei*. (c) Jurassic plant remains from Tiboburra; *Taeniopteris spathulatum* and *Taxites*.

Mr. E. J. Kenny addressed the section on "Some Aspects of the Geology of the West Darling District."

The distribution, lithology, structure and geological age of each major group of rocks occurring in this very wide area of 34,000 square miles were referred to, particular attention being given to the Jurassic and Cretaceous beds as exposed in the Tiboburra and White Cliffs districts. The important discovery of fossil plants of Jurassic age and of marine fossils of Lower Cretaceous age was mentioned and special reference was also made to the widespread distribution of glacial erratics in rocks of Lower Cretaceous age, which occupy a large proportion of the West Darling area.

The distribution of Tertiary marine rocks southwards from the Barrier Ranges was discussed. Information concerning these had been obtained from bore cores in which shells and sharks' teeth of Miocene (Janjukian age) had been noted. Leaves of a dicotyledonous plant, also probably of Tertiary age, were referred to as occurring in the siliceous capping of the Cretaceous rocks at White Cliffs.

Professor Cotton expressed the thanks of the meeting to Mr. Kenny for his instructive address concerning a little known area, in which the conditions for geological work are particularly difficult.

*June 19th, 1931.*

Mr. C. A. Sussmilch occupied the Chair.

Thirteen members and eleven visitors were present.

#### EXHIBITS

1. By Professor W. R. Browne, on behalf of Miss Dunnicliff—Amygdaloidal lavas and zeolites, with fossil wood enclosed in lava, from Coonabarabran. (Stated by Mr. Kenny to belong to the Garrawilla series of Jurassic age.)
2. By Mr. M. Morrison—Beryl crystals from Thackeringa.
3. By Mr. L. L. Waterhouse—Suite of fossiliferous limestones from Colo Creek, Capertee. The fossils included

*Receptaculites*, *Loxonema* and *Stromatopora*. Age: Middle Devonian.

Miss Ida A. Brown addressed the section on "The Devonian sequence on the South Coast of New South Wales, and its correlation with other occurrences in South Eastern Australia."

The sequence referred to was studied on the South Coast of New South Wales between the Shoalhaven River and the Victorian border. The Devonian rocks here rest with marked unconformity on highly-folded pre-Devonian sediments.

It was pointed out that three divisions of the Devonian Rocks may be recognised as follows:—

i.—A lower series of volcanic rocks—porphyries, quartz porphyrites and tuffs.

ii.—A series of freshwater or estuarine beds containing Upper Devonian plant remains with interbedded rhyolites, felsite and basalts.

iii.—An upper series of conglomerates, grits, sandstones and quartzites containing typical Upper Devonian fossils.

The three series are separated from each other by erosional breaks, and the upper (marine) are more widely distributed than and overlap the older series.

Tentative correlations with Devonian rocks of similar type in other parts of South-Eastern Australia were suggested, reference being made particularly to the Gippsland area in Victoria.

The palaeogeography of the Devonian was also briefly considered.

Discussion followed, which was contributed to by Sir Edgeworth David, Messrs. Andrews, Sussmilch and Dun, Professors Cotton, Browne and McDonald Holmes, and by Messrs. Waterhouse, Naylor and Raggatt.

*July 17th, 1931.*

Mr. C. A. Sussmilch occupied the Chair.

Eleven members and eight visitors were present.



## EXHIBITS:

1. By Mr. E. K. F. Naylor—Fossil flower from Tertiary beds at Bundanoon, probably *Leptospermum*.
2. By Mr. L. L. Waterhouse—(a) From Cranky's Falls, near Fitzroy Falls. Hematite concretion, polished by attrition, apparently due to its being turned round by impact of drops of water from above. (b) Chlorite in stanniferous quartz crystals from Torrington.
3. By Mr. H. F. Whitworth—Concretions of iron pyrites, surrounded by limonite from Triassic rocks, Wilde's Meadow, Moss Vale. These suggest a mode of origin for similar limonite concretions found in the Sydney District.

Professor W. R. Browne addressed the section, his subject being "Notes on the Physiography of the Upper Murrumbidgee."

The course of the Upper Murrumbidgee was described, together with those of its tributaries. In particular valley-in-valley structure was mentioned, there being well marked terraces or gravels at heights above the present river level of 50-60, 140-150, 240-250 and 400 feet. In contradistinction to the youthful tributaries which join the main stream on the left bank as far down as Tharwa, the Umaralla River, which joins it on the right bank, is mature and its tributaries occupy mature basalt-filled valleys.

At Michelago it was noted that the "valley" of the Upper Murrumbidgee is eight miles wide, the Tinderry Range forming the true eastern side of the valley. The carving out of this valley has been mainly the work of tributaries and not of the Murrumbidgee itself. It was pointed out that from Umaralla northwards the course of the Murrumbidgee is confined on the western side by the eastern boundary of a granite batholith, and on the eastern side by bars of porphyry such as form the high ground on the east side of the river near Michelago.

The lecturer considered that the evolution of the present stream pattern had thus been determined by erosion of rocks of differential hardness and not by faulting. It was also shown that the difference in the levels of the basalt near

Umaralla was due, not to faulting, but to difference in levels in the old topography upon which they rested.

The address was discussed by Sir Edgeworth David, Mr. E. C. Andrews and Mr. C. A. Sussmilch, Professor Browne briefly replying to points raised in discussion.

August 21st, 1931.

Mr. C. A. Sussmilch was in the Chair.

Seven members and two visitors were present.

#### EXHIBITS

1. By Mr. W. S. Dun on behalf of Mr. Carey—Specimens of fossil plants from Turrimetta Head. The specimens included plants which Dr. A. B. Walkom considered probably belonged to the genus *Todites*, both fertile and sterile examples being present. This constitutes the first record of the genus from the Narrabeen Series. Similar examples with somewhat larger pinnules have been recorded from the Esk Series in Queensland. At Turrimetta Head, the *Todites* is associated with *Thinnfeldia* and *Neocalamites*.

Dr. Anderson addressed the section on "The Ancestors of Man."

The subject was introduced by an outline of the orthodox view of man's line of ascent. The following types of early man were then discussed, reference being made to casts, skulls and other illustrations:—

- 1.—Neanderthal man (*H. Neanderthalensis*) of whom the first representative was found at Gibraltar in 1848. The type specimen was found in Neanderthal in 1857. Neanderthal man dates from about the time of the Riss ice stage.

- 2.—Heidelberg man. Considered by some research workers to be a robust example of *H. Neanderthalensis*.

- 3.—Rhodesian man, found in 1921. The skull found shows him to have been a very robust type of Neanderthal man.

- 4.—Piltdown man, found in 1927. The remains show a fairly high organisation as to head, but with an ape-like lower jaw.

Some doubt has been expressed as to their being part of the one specimen. Piltown man belonged to the early Pleistocene.

5.—Java man (*Pithecanthropus erectus*), of early Pliocene age had an ape-like skull cap and teeth, but probably had the rudiments of speech and appears to be quite entitled to admission to the genus *Homo*.

6.—Peking man (*Sinanthropus Pekingensis*). A skull cap was found in 1929 and the remains of twelve individuals later.

Mention was also made of the Talgai skull found in a gravel bed in a tributary of the Condamine River. The skull represents an early Australian type different from the modern aborigine.

The address was concluded by reference to other views of man's ancestry, such as those held by Wood-Jones, Tate-Regan and Osborn.

A general discussion centred about the principal exhibits referred to in the address, Dr. Anderson replying to the many questions asked of him.

*September 18th, 1931.*

Mr. C. A. Susasmilch was in the Chair.

Seven members and seven visitors were present.

#### EXHIBITS.

1. By Sir Edgeworth David—(a) On behalf of Captain A. C. Morris, laterite from the Gosford District, used as a road material. (b) On behalf of Misses Powell and Culey: specimens from gravel beds at Tuggerah Lakes identical with pebbles from Emu Plains, suggesting deposition by the same stream, an ancestor of the Hawkesbury River.
2. By Mr. M. Morrison—(a) A full section of a "kerosene" shale seam at Coolaway Mountain. (b) Wallaby excrement from Coonabarabran. (c) Tungsten ore (Scheelite, wolfram, iron and copper pyrites, bis-muthinite.) (d) Ore from St. Aignan's mine, Lucknow, showing free gold. (e) Free gold enclosed in arsenical pyrites from Nelligen. (f) Epidote in quartz from

'Crudine, near Sofala. (g) Quartz veins in granite from Boonoo Boonoo. (h) Graphite schist from Eyre's Peninsular, South Australia, now being worked for graphite. (i) Pencil-like piece of fibrous gypsum obtained from a locality 50 miles from Bourke. (j) Stichtite.

3. By Professor W. R. Browne—(a) On behalf of Mr. Carey from near Colinton: silicified phyllite. (b) From the Cooma-Colinton Ordovician rocks—a series of specimens showing structure; (i) sheared tuff or porphyroid rock showing puckering; (ii) puckered silicified limestone; (iii) schist showing relationship of bedding, folding and schistosity; (iv) silicified and banded chert-like rocks; (v) granitised mica schist, showing mullion structure.

Lantern slides were also exhibited in explanation of the exhibits and of the physiography of the region.

4. By Mr. W. S. Dun—(a) Specimen of *Isotelus gigas* from the Trenton of New York. (b) Specimens from Mudgee, collected by H. E. Barton, closely allied to *Mitchelldeania*? *Cribiformis*, Eth. fil. from Belubula and from Copper Hill, near Molong. They are probably more closely allied to the lime-secreting thallophytes than to the cœlenterates. (c) On behalf of the Australian Museum. Silicified *Cyathophyllum* and *Favosites* from Colinton.
5. By Mr. C. A. Sussmilleh—A series of specimens illustrating a sequence near Kandos of about 5,000 feet of strata, mainly referable to the Devonian.(?) Mr. Dun, in discussion, mentioned that there were no fossil types present in common with those of the Tamworth Area.
6. By Mr. H. G. Raggatt—Two pieces of bore core, showing miniature dyke and sill, from the Greta series at Muswellbrook.

October 16th, 1931.

Mr. C. A. Sussmilch occupied the Chair.

Eight members and four visitors were present.

EXHIBITS:

1. By Mr. W. S. Dun—A new Ammonoid, collected by Mr. Duniface, manager of Pelton Colliery, from the Upper Marine Series at Pelton. The specimen is an almost complete one, showing portion of the body chamber and well preserved septum and suture lines. It appears to represent a new member of the Glyphioceratidæ with 7 lobes as compared with *Paralegoceras* 11, *Agathiceras* 13 and *Schistoceras* 15. There is no close resemblance to any of the Timor Permian genera.
2. By Mr. H. O. Fletcher—on behalf of the Australian Museum, *Thinnfeldia* from Bronte.
3. By Miss Ida A. Brown—Specimens of limestone from Portland, coralline and highly altered, of Silurian age.
4. By Mr. T. Hodge-Smith—On behalf of the Australian Museum; *Billitonites* from the Philippines.

Mr. H. O. Fletcher, delivered a lantern lecture on Sir Douglas Mawson's recent Antarctic expeditions, dealing more particularly with the geological aspect. Sir Edgeworth David, Professor W. R. Browne and Mr. C. A. Sussmilch contributed to a discussion of the lecture.

November 20th, 1931.

Mr. C. A. Sussmilch was in the Chair.

There were ten members and five visitors present.

EXHIBITS:

By Mr. L. L. Waterhouse—A plane table constructed by Mr. G. Watts at a very small cost, and very efficient.

The recently issued paper by T. W. E. David and C. A. Sussmilch on "Upper Palaeozoic Glaciations of Australia," (Bull. Geol. Soc. America, Vol. 42, pp. 481-522, 1931), was read in brief by the authors and discussed by the meeting. Professors Cotton and Browne and Messrs. E. C. Andrews and W. S. Dun contributed to the discussion.

ABSTRACT OF THE PROCEEDINGS  
OF THE  
SECTION OF INDUSTRY.

*Officers: Chairman, A. D. Olle, F.C.S.; Honorary Secretary, H. V. Bettley-Cooke.*

During the year the following works were visited by the members:—

*May 12th.*—Engineering Department, Garden Island.

*June 9th.*—The Globe Worsted Mills, Marrickville.

*July 14th.*—Australian Paper Mills, Matraville.

*August 11th.*—The Bunnerong Power Station.

*September 8th.*—The Cancer Research Department, University of Sydney.

*October 20th.*—Kellogg (Aust.) Pty. Ltd., Botany.

*November 10th.*—Toohey's Brewery, Elizabeth Street, Sydney.

*December 8th.*—The Botanic Gardens, Sydney.

*December 9th.*—The Shale Oil Development Committee Ltd., Newnes.

ABSTRACT OF PROCEEDINGS  
OF THE SECTION OF  
PHYSICAL SCIENCE.

*Officers: Chairman*, Professor O. U. Vonwiller B.Sc., F.Inst.P.; *Secretary*, Assistant Professor G. H. Briggs, B.Sc., Ph.D., F.Inst.P.; *Assistant Secretary*, S. E. Williams, B.Sc.; *Committee*, Professors Bailey, Madsen, Wellish, Major E. H. Booth, Mr. J. Bannon, Miss P. Nicol.

The Section, during the year 1931, made certain changes in the conduct of its affairs, which are briefly as follows:—The Committee decided to formally associate in future, with the Section, advanced students of Physics in the University of Sydney and others not eligible for membership of the Royal Society; such members of the Section to elect two representatives to the Committee of the Section, one of whom may act as Assistant Secretary of the Section.

Thirteen meetings were held during 1931, the average attendance being 14.

*April 15th, 1931.*—Mr. Bannon—Demonstration and description of the Methods used in the Radium Laboratory, University of Sydney, in the purification of Radon.

*April 29th, 1931.*—Joint discussion with the N.S.W. Branch of the Royal Astronomical Association on the Constitution of Stars.



*May 13th, 1931.*—Mr. J. Raynor, B.Sc.—Electrical Methods of Geophysical Prospecting.

*June 10th, 1931.*—Associate Professor Bailey—Some Recent Scientific Experiences and Impressions in Europe.

*June 17th, 1931.*—Mr. R. L. Aston, M.Sc.—Milne's Theory of Stellar Constitution.

*July 1st, 1931.*—Mr. S. E. Williams—Atmospheric Potential Gradient: Its Measurement and Correlation with Meteorological Conditions.

*July 15th, 1931.*—Mr. G. Godfrey—The Mathematical Basis of Einstein's Unified Field Theory.

*August 5th, 1931.*—Professor V. A. Bailey—Some New Phenomena associated with Beams of Electrons.

*September 16th, 1931.*—Discussion of Professor Wellish's paper on Photoelectrons and Ions.

*October 7th, 1931.*—Discussion of Photographic Methods of Measuring Radiation Intensities.

*October 22nd, 1931.*—Assistant Professor G. H. Briggs—Recent work on the Relation of alpha and beta rays to gamma rays. Mr. H. J. Frost—Some curves obtained with thin plates in the infra red.

*November 4th, 1931.*—Mr. R. L. Aston—Surveying Instruments, with special reference to recent improvements.

*November 18th, 1931.*—Professor O. U. Vonwiller—Total Reflection of X rays.

THE PRODUCTION OF ZINC BY ELECTROLYSIS  
OF ZINC SULPHATE SOLUTIONS.\*

BY HARRY HEY.

With five text figures and one plate.

*Published as a Supplement to the Journal of the Royal Society of  
New South Wales, Vol LXV.. 1931.*

The public opening of the Faraday Exhibition in London less than 24 hours ago reminds us that it is but 100 years since Michael Faraday made the discovery in which lies the origin of the dynamo, and thus laid the foundation for the development of electrical machinery, which is the basic requirement for any electro-chemical industry. The first commercial "dynamo electric machine" was produced by Siemens in 1867 and from then onwards chemists, physicists, engineers and others have given a great deal of attention to applied electro-chemistry, of which the electrolytic zinc industry is an important branch.

The world's production of zinc during 1930 by all processes totalled approximately 1,400,000 tons, and the present annual capacity of plants using the electrolytic process aggregates approximately 550,000 tons. Australia's share is 55,000 tons, increasing to 70,000 tons when the Risdon extensions are completed. The power required for depositing zinc in the world's electrolytic zinc plants when on full production amounts to a continuous load of 270,000 H.P., D.C.

\* First Liversidge Research lecture delivered on 24th Sept., 1931, at Science House, Sydney, arranged by the Royal Society of New South Wales under the terms of the Liversidge bequest.

As recently as 1914 there was no electrolytic zinc industry. Its development has been truly remarkable. Its position to-day is an outstanding example of the application of rigid chemical control to large scale operations. The electrolytic zinc plant is really a laboratory on a large scale in which thousands of gallons, instead of litres, of solution are handled in tanks and pumps instead of beakers and pipettes. The removal of some impurities is carried to a degree farther than was previously necessary for the analytical determination of these same substances; new standards of analysis were necessary and new methods have been devised.

### History.

Australia—especially the State of New South Wales—was particularly concerned with the early attempts to develop the electrolytic zinc process. A large quantity of zinc-bearing by-product had accumulated at Broken Hill, and it was thought to be suitable for treatment by some such process.

Prior to 1913 literally hundreds of experimenters attempted to recover zinc by hydrometallurgical processes which, in many cases, involved the electrolysis of a solution of either zinc sulphate or zinc chloride. Accounts of their experiments are distributed throughout the literature of many countries, more especially in patent records, but it was not until 1914 that the modern electrolytic zinc process or, indeed, any commercial process involving the electrolysis of zinc sulphate solutions, can be said to have been established. Small plants were operating earlier in Germany and in England, using a zinc chloride electrolyte, but these plants have been closed and the chloride process abandoned. Unless otherwise specified any further reference will be confined to the sulphate process.

It is instructive to review the outstanding early attempts to produce electrolytic zinc. In 1881 Letrange obtained patents<sup>(a)</sup> for producing zinc by electrolysing zinc sulphate solutions. His process included roasting, leaching and electrolysis. He used sheet zinc cathodes and carbon anodes, but he did not succeed in producing zinc on a commercial scale. His work is of interest, chiefly because he used insoluble anodes; cells without diaphragms and an electrolyte containing free acid. It has been claimed by Ralston<sup>(b)</sup> that Letrange practically anticipated modern practice, but as far as can be determined at this date the only feature in common with present practice is the use of sulphate solutions containing free acid.

About 1891 Sherard Cowper Cowles (the inventor of the Sherardising process) was experimenting with the electro-galvanising of iron and steel articles, using zinc sulphate solutions, and some three or four years later he erected an experimental plant in Cornwall for recovering electrolytic zinc from the Broken Hill material already mentioned.<sup>(c)</sup> He removed copper and cadmium from the impure zinc sulphate solution (obtained by roasting and leaching) with scrap zinc or zinc dust, and he sometimes found it necessary to remove manganese. The solution purified in this way contained approximately 100 grams of zinc as sulphate per litre. He electrolysed with lead anodes and aluminium cathodes and he apparently also recognised that free sulphuric acid in the electrolyte improved the character of the deposited zinc. As far as the author knows, Cowper Cowles was the first experimenter to use aluminium cathodes, and it is likely that he also recognised the need for careful purification of the solution. He did not succeed in establishing the process on a commercial basis.

Probably the most ambitious unsuccessful attempt to produce electrolytic zinc commercially was made by Ashcroft at Cockle Creek, near Newcastle, in New South Wales, in 1897, following upon experiments carried out by him in Broken Hill and in England.<sup>(d)</sup> It is said that £250,000 was spent on this venture. His original intention was to electrolyse zinc chloride solutions, and, in fact, his plant was designed for and operated with such solution for most of its life, but for some weeks the electrolyte was zinc sulphate. He used diaphragm cells fitted with iron or zinc cathodes and lead and carbon anodes.

Ashcroft recognised that copper, iron, arsenic, antimony, etc., were harmful, and he also states that he had considerable trouble with manganese. However, subsequent work with Broken Hill ores has shown that Ashcroft's troubles were due mainly to cobalt, which he unknowingly precipitated when removing manganese from solution.

Early in the twentieth century, Englehart, Huth and Laszczynski, of the Siemens Halske organisation, made notable advances in the subject, particularly in respect of purification of solutions. They recognised that it was necessary to convert iron to the ferric state before it could be satisfactorily precipitated, and, in fact, patented a process involving the use of manganese dioxide for this purpose. Lime or zinc oxide was then added for precipitating the iron and with it certain other impurities, particularly arsenic and antimony, together with silicic acid. The staff of this organisation also proposed the use of moulded manganese dioxide anodes, but this type of anode has not been adopted in any commercial plant.

About 1910 the General Electric Company of America developed a sulphate process, the original basic feature of

which was the maintenance of a neutral electrolyte by feeding zinc oxide directly to the cells. Under these conditions the zinc deposit was spongy. Some years later an electrolyte containing free acid was investigated and Hansen, of this organisation, collected much instructive data respecting roasting, leaching, purification and electrolysis.<sup>(e)</sup>

All this preliminary work—some of it expensive—had failed to establish the process on a commercial scale, but it had served a very definite and useful purpose by indicating some of the pitfalls and had shown that the removal of certain impurities from the solution was essential for successful electrolysis. It is perhaps unfortunate that there was a mistaken idea that the electrolytic zinc process could only be justified for the treatment of those complex ores which could not be economically treated by the older distillation process. These ores contained many interfering substances (some of which consumed acid), and others were very definitely toxic, in that their presence in the electrolyte, in many cases even in minute quantities, prevented the satisfactory deposition of zinc. Most of the ores also contained excessive silicious material which formed soluble silicates during roasting.

The successful commercial production of electrolytic zinc was established with the completion of the plants erected in 1915 at Great Falls, Montana, U.S.A., by the Anaconda Copper Company, and simultaneously at Trail, British Columbia, Canada, by the Consolidated Mining & Smelting Company. These plants were erected primarily to satisfy the urgent demand for pure zinc for use in the manufacture of high grade brass, etc., required for munitions. Their construction followed an extensive series of investi-

gations, not only connected with the process reactions, but concerning the equally important development of the most suitable equipment, and it is to the credit of the organisations responsible that the modern equipment, and, in essentials, the process, is but little changed from the plants erected in 1915 and the practice followed there. The Tainton process, referred to later, is an exception to this generalisation.

Interest in the process was rekindled in Australia in 1916, when attempts were made to treat Broken Hill concentrates at Bully Hill, California, and at Broken Hill. Preliminary work showed that electrolytic zinc could be satisfactorily produced, but only after the recognition that cobalt was present in the Broken Hill concentrates and that it was a toxic impurity. In 1917, the first small scale plant was erected at Risdon, producing a few pounds of zinc per day; this was followed by a somewhat bigger plant, and this again by another which had an ultimate output of 25 tons per day. The latter plant was used for providing data on which to design the present plant which has an output of approximately 150 tons slab zinc per day.

Since 1917, many refinements have been introduced at all the plants, but the main principles of the process remain unaltered. There have certainly been many changes in practice which have enabled the recovery of zinc to be increased and/or costs to be reduced. This is the natural result of continued extensive research, both pure and applied, and to-day electrolytic zinc containing more than 99.9% zinc can be produced as cheaply as, if not more cheaply than, retort spelter of considerably lower grade produced by the old-established method of distillation from a mixture of zinc oxide bearing material and carbon.

**Outline of Present Practice.**

The three major objectives of the electrolytic zinc metallurgist are:—

- (a) Recovery of the maximum amount of zinc as zinc sulphate in solution from a given raw material;
- (b) Removal of dissolved impurities to the required degree as cheaply as possible and with the minimum loss of zinc; and
- (c) The deposition of zinc of maximum purity and satisfactory physical condition from the purified solution with the minimum power consumption.

These objectives are all inter-related, and to attain them the various operations, comprising the electrolytic zinc process in toto, have necessarily to be carried out under carefully controlled conditions.

The process is a cyclic one and the sequence of steps is:—

- (1) Roasting the raw zinc sulphide material under such conditions that the zinc sulphide is converted to zinc oxide and a controlled amount of zinc sulphate.
- (2) Leaching or dissolving the zinc oxide from the calcines produced in step (1), using spent electrolyte produced in step (4).
- (3) Purification, or removal of those impurities which either interfere with the electrodeposition of zinc or contaminate the deposit.
- (4) Electrolysis of the purified solution whereby it is depleted of portion of its zinc with the regeneration of equivalent sulphuric acid for re-use in the leaching step.
- (5) Melting the cathode zinc produced in step (4) and casting the molten metal into ingots for sale, and



- (6) Treatment of these residues or precipitates which contain substances having some value.

**Nature of Zinc Bearing Material Treated.**

Most of the raw material is obtained from mixed lead-zinc ores, which are treated by the flotation process for the production of lead and zinc concentrates. The former contains the bulk of the lead sulphide and the latter consists mainly of zinc sulphide contaminated with iron and other sulphides. The iron may be present as pyrrhotite or pyrite. Sometimes the former is free; sometimes it is in solid solution in the zinc sulphide mineral.

In addition, practically every zinc concentrate contains some siliceous gangue and traces of other impurities which, whilst small in amount, have a significant effect on the subsequent treatment of the concentrates and/or products obtained therefrom.

The zinc concentrates supplied to electrolytic zinc extraction plants contain 45-60% zinc, 4-12% iron and some lead and silver—all as sulphides.

Impure zinc oxide produced from lead blast furnace slag is also used at two plants.

**Roasting.**

The primary object of roasting is to convert the various sulphides to oxides. When a mixture of the sulphides of zinc and iron is heated under oxidising conditions such as apply during commercial roasting, some of the iron oxide combines with zinc oxide to produce zinc ferrite ( $\text{ZnO} \cdot \text{Fe}_2\text{O}_3$ ). As this substance is relatively insoluble in dilute sulphuric acid, any zinc oxide so fixed is not recovered during leaching. The amount of ferrite formed depends on the grain size of the iron oxide and zinc oxide and also upon the temperature at which the two oxides are in contact.

When the zinc mineral contains iron sulphide in solid solution the two oxides are formed in molecular contact, and under these conditions the whole of the iron oxide will combine with equivalent zinc oxide irrespective of roasting temperature. On the other hand, where the zinc sulphide and iron sulphide are in separate minerals, combination between the oxides can be minimised by controlling roasting temperature; for example, if a mixture of zinc oxide and ferric oxide in the ratio of 2  $\text{ZnO}$  to 1  $\text{Fe}_2\text{O}_3$  be heated at  $700^\circ\text{C}$  for 4 hours, 36% of the iron oxide is converted to ferrite. At  $1000^\circ\text{C}$  the conversion is 87% in the same period.<sup>(8)</sup>

Practically all the iron sulphide in the Broken Hill zinc concentrates is in solid solution in the zinc mineral, and consequently temperature control during roasting is not important, excepting in-so-far as it affects the output of any given furnace. The other notable Australian zinc-bearing ore—the Rosebery-Hercules ore of Western Tasmania—contains a small amount of iron in the zinc mineral and, in addition, much free pyrite, some of which is recovered in and contaminates the zinc concentrate. In this case roasting temperatures therefore affect the amount of zinc ferrite formed.

The silica contained in zinc concentrates is important because some of it always combines with the oxides of zinc and lead during roasting, and the amount increases with increasing temperature. The resulting silicates are soluble during leaching.

The figures of Table 1 represent the effect of roasting temperature on the solubility of the various impurities in dilute sulphuric acid. The amount of each impurity is relative to 100 grams of zinc.

TABLE I.

*Relationship between Roasting Temperatures and Solubility of various impurities in Calcines produced from Broken Hill concentrates containing 49% Zinc.*

Roasting Temperature.				700°C.	800°C.	900°C.
Zinc dissolved, Grams ..				100	100	100
Mn	"	"	..	0.90	1.10	1.58
Total Fe	"	"	..	0.70	0.55	0.71
Fe (ous)	"	"	..	None	None	None
SiO <sub>2</sub>	"	"	..	1.29	2.97	3.85
Cu	"	"	..	0.38	0.25	0.26
Cd	"	"	..	0.45	0.40	0.25
Ag	"	mgs.	..	30	56	75
Sb	"	"	..	3.2	1.4	0.9
Co	"	"	..	12.9	12.9	13.3
Cl	"	"	..	Trace	Trace	Trace

With increasing temperature the amounts of soluble manganese and silver increase, but less copper, cadmium and antimony dissolve.

As the result of improvement in metallurgical practice in Broken Hill, the zinc concentrates now produced there contain 52½% zinc, less silica and less copper than formerly.

Roasting is usually carried out in multiple hearth furnaces, and at most plants it is done in one operation. In Australia roasting is done in two stages. The first stage is carried out on the mainland at locations adjacent to superphosphate plants. The sulphur is reduced from 30% to 6%, of which 1½ to 2% is sulphur remaining as sulphates of lead, calcium and zinc. Sulphuric acid is produced from the sulphur dioxide contained in the roaster gases. Both the chamber and contact methods of making sulphuric acid are used.

The normal annual output of the Australian acid plants utilising zinc concentrate gases is equivalent to 70,000 tons of 100% acid when on full production. From this 215,000 tons of superphosphate are manufactured.

Considerable research was necessary before the manufacture of contact acid from zinc concentrate roaster gas became an established process, because the roaster gases contain interfering amounts of arsenic and chlorine compounds in addition to lead sulphate and calcine dust. Some of these impurities settle in dust chambers, but final purification is effected by saturating the gases with water and passing them through an electrostatic precipitator. The removal of lead sulphate, arsenic and chlorine compounds during this treatment is 100%, 99% and 92% of the respective amounts of these impurities entering the electrostatic precipitator.

The gases are subsequently washed to remove the remaining chlorine compounds, are dried and are passed through a platinum contact mass. This mass has now been in use for over four years without regeneration.

The roasted concentrates or pre-roast calcines produced at the various mainland roasting plants are forwarded to Risdon, and are subjected to the second or re-roasting stage, in which sulphide sulphur is reduced from  $4\frac{1}{2}$  to 0.5%, and the sulphate sulphur increased to whatever is necessary to replenish any mechanical or chemical losses of sulphuric acid or zinc sulphate during leaching. This at Risdon is equivalent to 3% sulphate sulphur in the calcines leached.

Another important function of the re-roasting operation is the elimination of chlorides which contaminate the partly roasted calcines. These are introduced at the various roasting plants in the water used for wetting these calcines to minimise dusting during shipment to Risdon.

Chrome steel has replaced the cast iron and cast steel previously used for roasting furnace rabble arms. The Australian furnaces used in the first stage have been fitted

since 1920 with rabbles of alloy steel containing 27% chromium. This steel will withstand a temperature of 900°C continuously for 12 months or more without serious oxidation or failure from other causes. Other alloys containing chromium, nickel and tungsten or silicon are giving encouraging results at Risdon.

### *Leaching.*

The spent electrolyte returned to the leaching plant from the electrolytic cells is of varying sulphuric acid concentration. The concentration is fairly regular from day to day at any one plant. Only portion of the zinc is removed during electrolysis; therefore all these solutions contain zinc sulphate.

Three distinct methods of leaching are practised at various plants. These are:—

- (1) Batch leaching, where the roasted zinc concentrate, usually referred to as calcines, is added to a given volume of leach solution. It is usual to add the calcines in more than one stage and to continue this addition until the acidity of the solution has been reduced to a predetermined figure. The solution obtained is subsequently treated for the removal of iron, arsenic, antimony and silver, which is referred to later.
- (2) Two-stage continuous counter-current leaching, the equipment for which consists of two series of leaching vessels, four or more in each series, together with settling or thickening equipment. Partially leached calcines and spent electrolyte are fed continuously into the first vessel of one or "acid" series. During its passage through the series the zinc oxide is completely dissolved. The mixture overflows the

last vessel of the series and is settled and filtered. The residues are discarded. The solution which still contains acid is mixed with new calcines and fed through the second or "neutral" series of leaching vessels in which the acid is completely neutralised, but only portion of the zinc oxide is dissolved from the new calcines. There thus remains free zinc oxide, some of which reacts with and precipitates the iron, arsenic, antimony, silica and some of the copper which had dissolved during the other leaching stage. The mixture is settled and the solution overflowing the settlers or thickeners is sent forward to the purification section. The settled solids are mixed with spent electrolyte and the mixture is sent on to the first leaching stage.

At some plants the spent electrolyte is divided over both stages, but in all cases the solution overflowing the "acid" leaching series contains free acid and the overflow from the "neutral" series is neutral or basic.

- (3) For this method of leaching the calcine is separated into two products—a magnetic portion, which contains the bulk of the zinc ferrite, and the non-magnetic portion, which is said to contain the free zinc oxide and any gangue material. As ferrite is soluble in sulphuric acid of moderate strength at relatively high temperatures, the magnetic portion is first leached with the spent electrolyte, and after most of the ferrite is dissolved, the non-magnetic portion is added to the partially neutralised solution which, incidentally, contains ferric sulphate equivalent to the zinc ferrite dissolved. The iron is precipitated as basic sulphate along with silica, and

these remain with the insoluble portion of the residues after settlement and filtration.

This method, (3), which can be operated either continuously or intermittently, is usually only applied where high acid spent electrolyte is available. Filtration which is difficult enough with a saturated solution of zinc sulphate is made more difficult by the presence of much basic sulphate of iron. The method was developed in conjunction with the Tainton process which operates under high acid electrolysis conditions.

The batch method (1) was the procedure originally followed at the Trail and Anaconda plants, and, after leaching, a small amount of lime or limestone was added to the mixture of residue and solution to precipitate iron, silica, arsenic and antimony. Since 1920, however, the second method has been applied at these plants and it has become the general practice at most of the more recent plants.

The advantages of the second method are:—

- (a) The solution, immediately prior to leaving the leaching circuit, is in contact with zinc oxide, thus ensuring nearly complete precipitation of iron, arsenic and antimony, and
- (b) The residues are discarded from an acid pulp; the maximum amount of zinc oxide is thus recovered.

Its disadvantages are:—

- (c) The residues are thickened twice, and
- (d) The discarded residue contains the precipitated silicic acid and basic iron salts which make filtration difficult.

A modification of the batch leaching as described under (1) is used at Risdon and leaching is continued until the acidity is reduced to two grams sulphuric acid per litre. When separated from the solution, the residues, which are practically free from precipitated iron or silica, are in a satisfactory physical condition for subsequent treatment for recovery of lead and silver.

The residues from the leaching stage contain zinc ferrite and zinc sulphide which was not oxidised during the roasting of the zinc concentrates, and some undissolved zinc oxide, together with insoluble gangue material. The zinc sulphide and zinc oxide are contained in the coarser particles, and at Risdon this coarse material is separated from the finer residues and is subjected to further treatment which comprises, firstly, fine grinding and leaching with spent electrolyte, and, secondly, treatment in flotation machines for the recovery of the zinc sulphide as a concentrate which is roasted and leached. The residues from the flotation machine join the fine residues from the major leaching operation and the mixture is settled in thickeners. The settled solids are then filtered.

The filtered residue contains most of the lead and silver originally in the concentrates and is shipped to Port Pirie for treatment.

#### **Purification of the Solution.**

*Removal of Iron, Silica, Arsenic and Antimony.* The zinc sulphate solution obtained by applying the two-stage continuous counter-current leaching method (2) is practically free from iron, arsenic and antimony, and the silica which dissolved has been precipitated. These impurities have been discarded in the leach residues. The solution still contains copper, cadmium and manganese, and in some cases cobalt. On the other hand, the solution obtained at



Risdon by the single stage batch process contains all the impurities dissolved during leaching in addition to 2 grams free sulphuric acid per litre. Neutralisation of the acid and precipitation of the iron, silica, antimony and arsenic is effected by treatment with finely ground limestone and the precipitate—which is composed mainly of gypsum, basic ferric sulphate and hydrated silica—is coagulated by prolonged agitation. For rapid filtration it is essential that there be sufficient gypsum crystals in the precipitate to provide a support for the gelatinous iron and silica precipitates. The presence of ferric iron is necessary for the removal of arsenic and antimony.

The *modus operandi* at Risdon is the result of considerable investigation and, so far as the author knows, it is the only plant where this procedure is followed. The precipitate contains a small amount of coagulated silver chloride, which is removed by washing the filtered precipitate with sodium thiosulphate. The wash water goes forward with the main solution.

With any method of leaching it is necessary to convert any dissolved ferrous sulphate to the ferric condition. Agitation with air during leaching usually does this but it is necessary to add manganese dioxide when much ferrous iron is present.

The recovery of zinc from the calcines is determined largely by the thoroughness with which the residues and, at Risdon, the limestone precipitate, are washed. Because of the cyclic nature of the process, the permissible amount of wash water is definitely limited to the amount of the solution discarded with the residues and the water lost by evaporation, due to circulation of the solution. Water was originally added to the calcines at Risdon to minimise

dusting during the handling of this material between the reroasting furnaces and the leaching section. In recent years, however, zinc sulphate circuit solution has been substituted, and thus no new water goes into the circuit at any point other than as wash water through the residues or limestone and other precipitates.

The circuit solution is cooled at Risdon by running it down towers under conditions whereby cooling of the solution is brought about by evaporation of water. Water equivalent to that evaporated is available for use as wash water.

*Removal of Copper and Cadmium.* The next stage in the preparation of the solution is the removal of copper and cadmium. Hydrogen sulphide and various sulphides have from time to time been proposed for this purpose, but zinc dust is in universal use. Nearly complete removal of copper can be effected by agitating the solution with equivalent zinc dust, but the precipitation of cadmium requires excess over that theoretically necessary. Most of the antimony and arsenic which has escaped precipitation during the preceding step is removed with the copper and cadmium.

In the original Anaconda plant, the mixture of zinc dust and solution was agitated by using compressed air, and this practice was followed until recent years. The trend at Risdon has been to take extreme precautions against introducing air into the purification tanks; in fact, the purification section was remodelled some time ago in order to prevent ingress of air through the glands of the pumps handling the mixture of precipitated copper and cadmium and solution between the tanks and the filter presses.

The solutions at Risdon prior to zinc dust purification contain approximately 250 mgs. of cadmium and 200 mgs.

of copper per litre, but the amounts vary over a fairly wide range from day to day. In order therefore to confine the consumption of zinc dust within the lowest possible limit, it is an advantage to know the actual concentration of copper and cadmium in the solution going to the purification tanks. Within the last year a method has been developed at Risdon for the quick electrolytic estimation of copper and cadmium, using a mercury cathode. Analyses obtained in this way are used as the basis for calculating the amount of zinc dust to be added.

At the present time the precipitation of the two impurities is done in batches. An ingenious continuous process has been developed, but for economic reasons it has not been adopted.

At most of the electrolytic zinc plants, the solution is suitable for electrolysis after treatment with zinc dust. It is true that many of the zinc concentrates treated in these plants contain some cobalt, but usually in insufficient amounts to cause trouble during electrolysis. It accumulates in the circuit solutions until the concentration is such that the amount of solution discarded from the plant in the various residues contains as much cobalt as is introduced each cycle. For example, if one-tenth of a milligram of cobalt per litre were introduced during each leaching cycle, and if 1% of the circuit solution were discarded as indicated, the amount of cobalt discarded would be equivalent to the amount introduced when the concentration in the circuit solution reached approximately 10 mgs. per litre.

*Removal of Cobalt.*—At Risdon appreciable amounts of cobalt dissolve from the Broken Hill concentrates, and the amount dissolved in each cycle must be removed. Because of this the Risdon practice from this stage

onwards differs from most of the other plants. Zinc dust will precipitate cobalt from a water solution of its sulphate, but has very little effect in the presence of a large amount of zinc sulphate; consequently, the removal of cobalt during zinc dust treatment is negligible.

Many reagents oxidise cobalt if manganese is also present, and in this condition it is easily precipitated. The permanganates, lead peroxide and calcium plumbate, have been used for this purpose. With solutions containing much manganese, as is the case at Risdon, the cost of these reagents is excessive because it is necessary to oxidise all the manganese before the cobalt can be precipitated. Methods based on the use of the reagents mentioned have been investigated at Risdon, but only two methods which are of a different type have been used on a plant scale. These are:—

- (1) The so-called “arsenic purification” method, in which cobalt is co-precipitated with arsenic and copper by the addition of zinc dust. In practice, sodium arsenite and copper sulphate are added to the solution, which is heated and then treated with zinc dust. The cobalt, arsenic and copper are precipitated together. It is an expensive method, because zinc dust consumption is high and it is necessary to heat the solution.
- (2) The precipitation of cobalt by nitroso beta naphthol from the cold copper and cadmium-free solution. This was suggested in 1917, but has only been applied regularly on a commercial basis during recent years. In practice the calculated
  - amount of sodium beta naphtholate is added to the solution, then sufficient sodium nitrite and finally sulphuric acid to form the nitroso salt in

the solution. The cobalt is precipitated as the characteristic red cobalt-nitroso beta naphtholate, and the mixture of the precipitate and solution is neutralised with sodium carbonate. About  $9\frac{1}{2}$  lbs. of beta naphthol and equivalent sodium nitrite are required for precipitating 1 lb. of cobalt.

The latter method has entirely superseded the "arsenic purification" process, and is one of the major developments which has rendered possible the change in electrolytic procedure which is referred to later.

The cobalt in the solution feeding the electrolytic cells at Risdon is maintained at about 10 mgs./litre. The spent electrolyte contains a similar amount. Approximately 10 mgs. are introduced into the solution, each leaching cycle, and thus the solution after leaching contains 20 mgs./litre. It is therefore necessary to remove cobalt from 50% of the solution, each cycle to maintain the required concentration in the feed to the cells. About 60lbs. of cobalt are removed from the solution daily. Until two years ago the Risdon electrolyte contained 70-80 mgs. cobalt per litre, and the removal of cobalt from a much smaller volume of the solution was sufficient to maintain the cobalt concentration constant.

*Removal of Chlorides.*—The other purification stage concerns the removal of chlorides. The electrolyte is maintained at about 75 mgs. chlorine as chlorides per litre, and it is necessary to purify sufficient solution to take care of any chlorides introduced during leaching. The precipitation is effected by silver sulphate; the silver chloride produced is separated by filtration and is reconverted to silver sulphate by treatment with zinc dust and heating with sulphuric acid, when hydrochloric acid is volatilised to waste.

Those portions of the solution treated for removal of cobalt and/or chlorine join the main copper and cadmium-free solution. The combined solution after addition of glue is in suitable condition for electrolysis.

At Risdon the daily volumes of solution treated in leaching and the various purification stages are:—

During leaching . . . . .	600,000 galls. — 16,000 gallon batches.
For removal of Iron, Arsenic, etc. . . . .	600,000 galls. — continuously.
For removal of Copper and Cadmium . . . . .	600,000 galls. — 14,000 gallon batches.
For removal of Cobalt . . . . .	300,000 galls. — 14,000 gallon batches.

Portion of the solution is treated intermittently as required for removal of chlorine.

In some stages the circuit solution is very corrosive, as it contains ferric and copper sulphate and free acid. There have been many corrosion problems in connection with pumps, filters, launders and tanks. It has been found that celery top pine grown in Tasmania resists the action of acid zinc sulphate solution better than does any other timber yet experimented with at Risdon. Acid-resisting bronze and Staybrite are used for some metal parts, but wherever possible the flow sheet of the plant is arranged so that corrosive solution flows by gravity through lead pipes.

Over 100 tons of leach residues and 30 tons of limestone precipitate are filtered from the solution each day. Filtration problems arise and they are investigated, with the result that the filtration technique has gradually improved over a period of years.

The partial analysis of the solution after purification is given in Table II.

TABLE II.

*Analysis of Risdon Cell Feed Solution.*

Zinc .. .. .	= 114.9 g/l	Total Nitrogen	= 245 mgs/
Manganese ..	= 13.1 "	Ammonia	
Magnesium ..	= 1.75 "	Nitrogen	= 215 "
Sodium .. . .	= 9.16 "	Nitrite ..	= 9 "
Potassium ..	= 1.71 "	Calcium .. ..	= 440 "
Sulphate (SO <sub>4</sub> )	= 222.22 "	Phosphate (PO <sub>4</sub> )	= 2.1 "
Cobalt .. . .	= 10.0 mgs/l	Aluminium ..	= 0.5 "
Copper .. . .	= 0.6 "	Lead .. . . .	= 0.025 "
Cadmium .. .	= 6.4 "	Bismuth .. .	= Nil
Silica .. . .	= 80.0 "	Nickel .. . .	= Nil
Chlorine .. .	= 75.0 "	Selenium .. .	= Nil
Iron .. . . .	= 1.55 "	Tellurium .. .	= Nil
Arsenic .. .	= < 0.1 "	Tin .. . . .	= Nil
Antimony .. .	= 0.11 "	Glue .. . . .	= 27 mgs/l

The Specific Gravity is 1.334.

The solution is analysed daily for zinc, cobalt, antimony, copper, cadmium and chlorides. Rigid control during purification and accurate analysis enable the concentration of impurities in the cell feed solution to be maintained within very narrow limits.

**Electrodeposition.**

All zinc sulphate solutions are electrolysed under the general conditions of the two following processes:—

- (1) The so-called low acid, low current density process where the feed solution contains 100 to 150 grams of zinc per litre. The sulphuric acid concentration during electrolysis is 90 to 140 grams per litre, and the current density varies between 25 and 45 amperes per square foot at various plants. The zinc and acid concentration and current density are maintained at fairly constant figures at any one plant.
- (2) The Tainton high acid, high current density process operating with feed solution containing 215

. grms./litre zinc. The acidity of electrolyte is maintained at 280 grms./litre sulphuric acid, and the current density is 100 amperes per square foot.

The end products of electrolysis are zinc, sulphuric acid equivalent to the zinc, manganese dioxide, oxygen and some hydrogen. Portion of the hydrogen is produced by the direct electrolysis of water, but some results from the re-solution of zinc already deposited.

The so-called low acid, low current density process is applied at Anaconda, Trail, Risdon and other plants, and in fact, about 95% of the world's output of electrolytic zinc is produced by this process. Certain advantages have been claimed for the Tainton high acid process, principally in connection with the capital cost of plant because of the smaller volume of solution to be treated for a given output of zinc, and because of the heavier deposit of zinc per unit of cathode area. Another claim is that the high current density counteracts the effect of impurities in the electrolyte. Actually, there is little, if any, saving in capital costs after providing the more elaborate plant necessary to treat a hot, practically saturated, solution of zinc sulphate and to withstand the more corrosive high acid solution. Furthermore, electrolysis is conducted at a very high acidity in order to keep power consumption within reasonable limits, and thus most of the benefit expected from using a high current density is not realised in practice.

In the plants using the low acid, low current density process the cells are rectangular boxes constructed either of timber, lead lined, or of concrete, lined with a mixture of sulphur and sand. They are in series, usually six in number, and are so arranged that the spent electrolyte overflows the first cell of the series into the second and so on through the whole series.



The cathodes at all plants are aluminium sheets,  $\frac{1}{8}$  in. to  $\frac{3}{16}$  in. thick, from 2ft. to 3ft. long by 2ft. wide. The sheet aluminium is riveted to a copper head-bar which rests on the busbar. The anodes are cast lead,  $\frac{1}{8}$  in. or more thick, and are usually somewhat smaller than the cathode in area. Each anode is cast around a copper head-bar, which rests on the appropriate busbar. The anodes quickly become coated with lead peroxide or manganese dioxide or a mixture of the two, and these oxides form the actual anode surface.

The number of cathodes in each cell varies at different plants. They are connected in parallel to the cathode busbar, and the anodes are hung between cathodes and are also connected in parallel to their busbar. The space between the surfaces of the cathode and anode varies from 1½ in. to 2½ in. at different plants.

The neutral purified solution is usually fed in parallel and in equal amounts to all the cells in one series, or else to all cells excepting the last in the series. Thus the acidity in each of the cells to which feed solution is added is identical.

There are 504 cells at Risdon arranged in three large units of 144 cells each and 1 small unit. Each cell contains 33 cathodes and 34 anodes. The submerged area of both sides of each cathode is 13.0 sq. ft. and the corresponding area of the anode is 11.15 sq. ft. There are approximately 16,000 cathodes in constant use with an aggregate area of more than 200,000 sq. ft.

The electrical circuit in each 144 cell unit is approximately 12,000 amperes at 520 volts, which is equivalent to 3.61 volts per cell.

Each cell is provided with cooling coils, through which cooled water is circulated in amount sufficient to maintain

the temperature of the electrolyte within the prescribed limits.

Diaphragms are not used in any modern zinc cell.

The objective during electrolysis is the maximum economic yield of zinc from the available power. It is possible by costly purification and extra cell-room supervision coupled with the removal of the deposited zinc at more frequent intervals to appreciably increase the yield per unit of power beyond that attained in practice, but the electrolytic zinc industry is like every other industry in that any increase in technical efficiency must always be compared with the cost of obtaining it.

In the literature concerning zinc electrolysis, frequent reference is made to "Current Efficiency," "Cell Voltage" or "E.M.F." and "Yield of Zinc per Unit Power." A definition of each of these terms follows:—

*Current or Ampere Efficiency* is the yield of cathode zinc expressed as a percentage of that theoretically possible from the current employed in the cell. The theoretical yield is 1.219 grms. of zinc per ampere hour.

*The Cell Voltage or E.M.F.* is the drop in potential across the cell between the terminals of the anode and the cathode, and is the sum of the anode potential, cathode potential and the volt drop due to the resistance of the electrolyte. The anode potential may be defined as the difference in potential between the anode and the solution immediately in contact with the anode. The cathode potential may be similarly defined as the difference in potential between the cathode and the solution in contact therewith. It is obvious that with a given current efficiency, the energy consumption in the cell is directly proportional to the cell voltage.

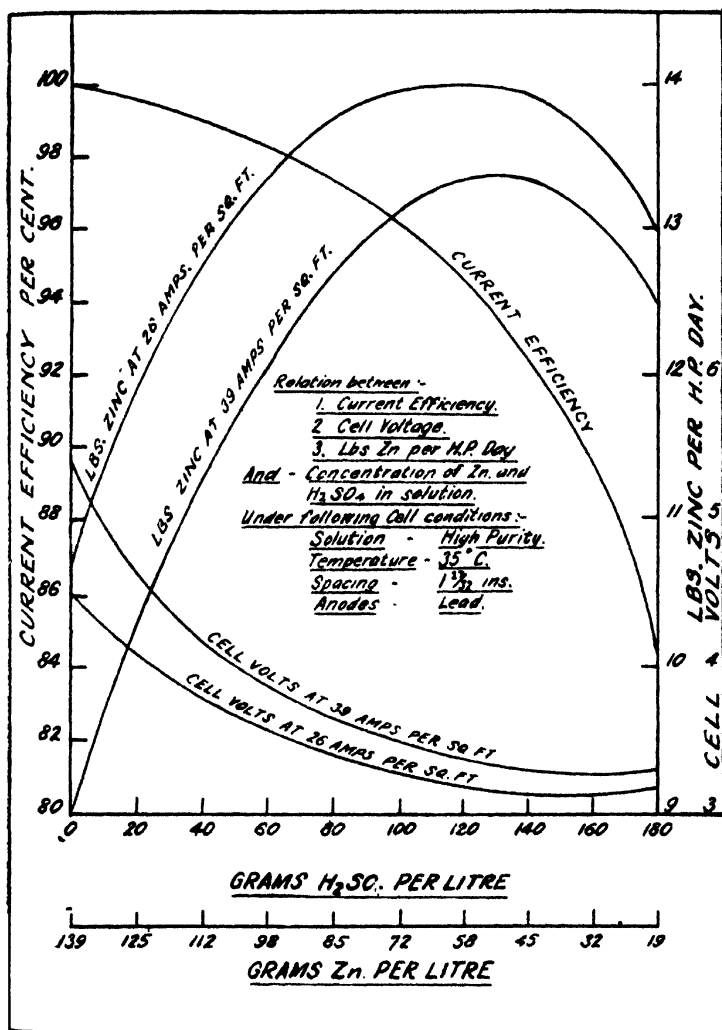
*The Yield of Zinc per H.P. Day or Kw. Hour, D.C. is a function of the current efficiency and cell voltage.*

The current efficiency is used as a measure of the electrolytic efficiency from day to day with an electrolyte of a given composition and system of electrolysis, and ranges between 90% and 93% at various plants. It varies with minor fluctuations in the purity of the solution, and generally it can be stated that it is a measure of the efficiency of the purification stage of the process and also of the care with which electrolysis is conducted.

Cell voltage, on the other hand, which should be nearly constant from day to day in any given plant, varies between different plants.

The inter-relation between current efficiency, cell voltage and yield of zinc at varying acidity is expressed in Figure I, in which is correlated the data obtained from the laboratory electrolysis of a highly purified solution originally containing 139 grams of zinc per litre. The solution used was the purest it has been possible to prepare at Risdon from the purest available materials. It was electrolysed at the temperature and electrode spacing mentioned. It is not directly comparable with the figures obtained on a Works scale, but any plant solution can be examined in much the same way as the pure solution referred to in the curves, if due allowance is made for deposition time. With pure solutions the time effect is not nearly so marked as when impurities are present.

The variables which affect current efficiency or cell voltage or both, and which therefore must be considered in determining the optimum conditions for the electrolysis of any given solution are:—

— **FIG. 1.** —

- (1) *Current Density.* . This has little effect on current efficiency unless toxic impurities are present, but the cell voltage increases with increasing current density. It is obvious that whilst a decrease in cell voltage is desirable, a decrease in current efficiency is not.
- (2) *Acidity.* An increase in acidity generally reduces cell voltage, but adversely affects current efficiency. The optimum acidity varies according to the amount and nature of the impurities in the solution.
- (3) *Zinc Concentration.* This is usually increased when operating with higher acid because C.E. increases with an increase in the  $\text{ZnSO}_4/\text{H}_2\text{SO}_4$  ratio.
- (4) *Anode Material.* Although lead is used as the original anode, the actual anode surface is usually a mixture of the peroxides of lead and manganese. The presence of certain other oxides derived from impurities in the electrolyte sometimes affects the anode potential and therefore the overall cell voltage.
- (5) *Temperature.* Cell voltage and current efficiency both decrease with increasing temperatures with most plant solutions.
- (6) *Length of Deposition Period.* Overall current efficiency decreases rapidly with time once cathode corrosion has started.
- (7) *Spacing between Electrodes.* The smaller the gap the lower the cell voltage. This benefit is to some extent offset by the greater danger of shorting and consequent reduction in current efficiency.
- (8) *Addition Agents.* Substances, such as glue, silicic acid, various gums, etc., are usually added to counteract the effect of impurities.

- (9) *Impurities in the Electrolyte*, either dissolved or suspended.

The conditions under which electrolysis is carried out are governed largely by the nature and amount of impurities present in the solution after standard purification; the effect on labour costs, and on the life of the lead and aluminium electrodes.

The more important data respecting the electrolytic practice at Anaconda, Trail and Risdon are:—

	Anaconda	Trail	Risdon	
Zinc concentration of feed solution gm/l . . . . .	110	150	Present 115	2 yrs. ago 113
Acid in Cell Discharge gm/l $H_2SO_4$ . . . . .	105	135	90	65
Current Density amp/sq. ft. Cathode . . . .	30	30-45	27.5	28
Temperature of electrolyte °C . . . . .	35-45	30-40	34-37	34-37
Deposition period, hours . .	24	24	72	72

The change from 65 to 90 grams acid at Risdon has appreciably increased power efficiency and was made possible by the substitution of the "beta naphthol" method for the "arsenic method" for removing cobalt. It is now economically possible to operate with an electrolyte containing 10 mgs. instead of 70 mgs. cobalt. Before making the change, 2 years intensive research on electrolysis was necessary and some hundreds of tests were made.

The most notable difference between practice at the three plants mentioned is that of the deposition period, which is three times as long at Risdon as at the other plants. Despite this, the Risdon current efficiency is between 91-92%. For some months, when cathodes were stripped every 48 hours, the current efficiency was approximately 1% higher, and daily stripping gives a still higher figure. The advantages of a 72 hour over 24 hour deposition period

are, firstly, low labour charge per unit weight of zinc produced because the cathodes are stripped less often, and, secondly, the cathode zinc is three times as thick and thus gives a higher yield during melting. The penalties are that the yield of zinc per unit power is somewhat lower, and greater control is necessary in respect of condition of the solution. The balance between the advantages and penalties is dependent largely on the selling price of zinc and on local conditions.

With 24 hour deposition, the Risdon cell acidity could, if desired, be increased to the Anaconda figure and, with increased zinc concentration as well, to that of Trail.

#### **Effect of Impurities on Electrolysis.**

All commercial zinc sulphate electrolytes contain impurities, some of which are harmless, some are deposited with the zinc, and others, even when present in small amounts, have a profound effect on electrolysis. The latter are usually referred to as toxic impurities, which include amongst others antimony, cobalt, arsenic, nickel, copper and germanium.

Some impurities which have no deleterious effect when present alone in small amounts sometimes accentuate the toxic effect of others. On the other hand, there is very definite evidence that one, at least, which is generally recognised as toxic has a beneficial effect when used in homeopathic doses under certain conditions. The fact that the joint behaviour of two impurities frequently differs greatly from that expected from their individual effect, undoubtedly explains why there is so much difference of opinion respecting this general question. The effects of the more important impurities have been studied, some in great detail, but in a lecture of this type, generalizations only

can be made, because variations in acidity, etc., have an important bearing on results, and to properly survey the effect of even one impurity would entail a study of a large amount of elaborate data.

*Manganese.* Of the heavy metals, manganese is by far the most common impurity in the electrolyte; indeed, it is doubtful whether any electrolyte obtained from flotation zinc concentrates is entirely free from it. It accumulates in the circuit until it reaches the concentration at which the rate of deposition as manganese dioxide at the anode balances the amount of manganese sulphate introduced during leaching. The rate of deposition as the dioxide varies with the acidity of the electrolyte, the condition of the anode surface, the nature of other impurities present and the addition agents used. Under present Risdon conditions the equilibrium manganese concentration is approximately 13 grams per litre.

Manganese has little effect on current efficiency under normal conditions, but it does reduce the conductivity of the electrolyte and therefore increases cell voltage. The removal of manganese dioxide which precipitates at the anodes and collects in the lower part of the cell, entails some labour charge. Unfortunately this product always contains lead peroxide and lead sulphate, and thus has little commercial value.

*Sodium, Potassium and Manganese Sulphates.* These sulphates are all present in the electrolyte and usually have little effect, excepting again on the conductivity of the solution. Some zinc concentrates contain so much magnesium that it is necessary to discard spent electrolyte to maintain a reasonable magnesium concentration in the circuit.



*Cadmium.* Any Cadmium present in the electrolyte is deposited with the zinc and reduces its grade. Apart from this, it has little effect.

*Lead.* Lead is present in all cathode zinc and most of it originates from the anode. The condition of the anode surface largely determines the amount deposited with the zinc, and it may be reduced by using a diaphragm between the anode and cathode, which prevents migration of lead. This, however, is not practicable.

*Toxic Impurities and Addition Agents.* Before discussing the effect of toxic impurities, it is necessary to comment on the use of addition agents which are used during electrolysis to counteract or control the effect of such impurities. Various substances have been suggested, including a number of gums and silicic acid, but glue is the universal reagent, particularly for electrolytes containing cobalt, and its use gives most remarkable results. Most operators use some glue, but because of the relatively large amount of cobalt in Broken Hill concentrates the electrolytic procedure at Risdon has been moulded around its use, and it is probably the most important factor contributing to the successful electrolytic treatment of these concentrates.

The mechanism of the action of glue is as yet somewhat of a mystery. Its effects, however, are most striking. Cathode zinc contains nitrogen, whether as glue or one of the decomposition products is not known. It has been suggested that glue migrates to the cathode and forms a film through which zinc ions can pass, but which resists, for example, cobalt ions. The alternative suggestion is that it forms a complex with cobalt and thus interferes with its deposition. Whilst little is known of the way glue functions, we are grateful for its effect.

The most prevalent toxic impurities present in zinc sulphate electrolytes are cobalt and antimony, but there are usually also traces of copper and arsenic and sometimes nickel.

Various investigators have attempted to determine the effect of both cobalt and antimony, but it is difficult to obtain agreement between the results of the different observers, for the reason already stated that traces of some impurities have a profound effect on the behaviour of others.

The toxic effect of most impurities which reduce current efficiency, is accentuated by increase in time of deposition, concentration of the impurity, temperature of electrolyte, acidity of electrolyte and also by decrease in current density.

*Cobalt.* The toxicity of cobalt was first recognised during the experimental treatment of Broken Hill concentrates in 1916, and about that time it was discovered that its ill effect could be controlled by addition of glue. The early discovery of the effect of glue enabled the Australian industry to be established on a commercial footing, but despite this, the removal of cobalt or its control during electrolysis has continuously occupied the attention of the Risdon technical staff.

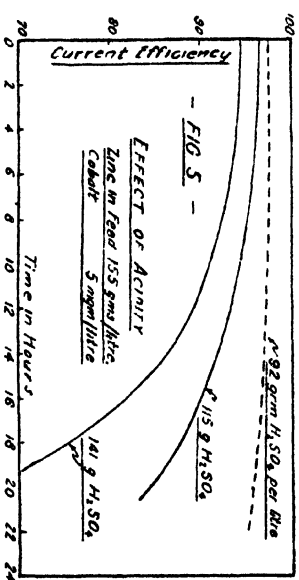
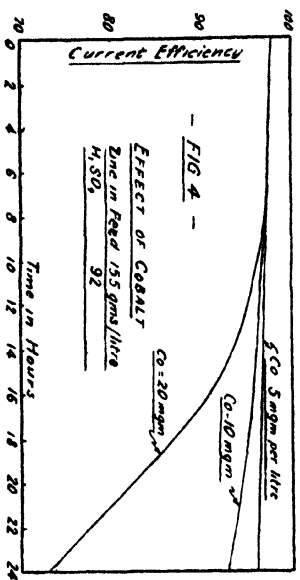
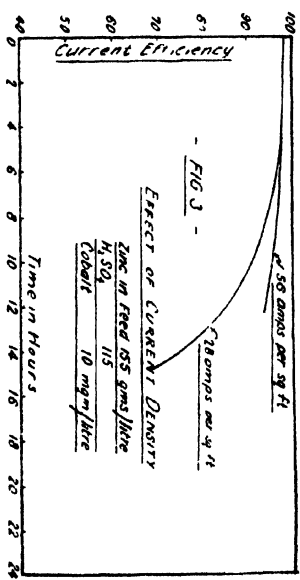
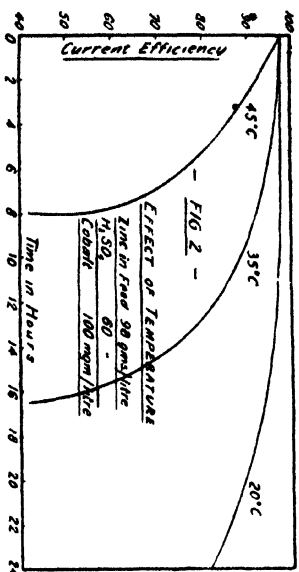
Laboratory studies have been made of zinc sulphate solutions containing cobalt as the only impurity, and of the Risdon plant solutions. Figures 2 to 5 show the effect of temperature, acidity and current density when electrolysing solution (otherwise highly purified) to which various amounts of cobalt have been added. The concentration of zinc, acid and cobalt are stated on each graph. They are not identical in each case, and the ones used were chosen to emphasize the effect of the variable being investigated.

Cobalt was the only impurity in the solution other than traces of silicic acid.

Tests with high cobalt Risdon plant circuit showed that a solution containing as much as 70 mgs. of cobalt per litre, can be electrolysed at 20 grams acid per litre, and 30 amperes/sq. foot to give a current efficiency of 96% during 48 hours deposition without glue. The same solution electrolysed at 55 grams per litre, and with the other conditions unchanged, gave extremely poor cathodes after only 19 hours deposition. No attempt was made to determine current efficiency, as zinc was dissolving from the cathode after 12 hours only, and from then onward current efficiency was nil or thereabout. A similar test was made simultaneously, using glue as an addition agent, and a most excellent deposit was obtained. The solution containing glue could have been electrolysed for 72 hours with good current efficiencies. These two cathodes (a) without glue, and (b) with glue (conditions otherwise similar), obtained after 19 hours deposition are shown in Figure 6. The photograph shows the zinc deposits on the aluminium cathodes.

Cobalt has a beneficial effect on the anode potential, and therefore on the cell voltage. With a current density of 30 amps. the anode potential at a lead anode is lowered by 0.15 volts when the electrolyte contains 100 mgs. of cobalt per litre. Assuming an overall cell voltage of 3.65, the reduction is equivalent to 4%, which has a marked beneficial effect on power consumption. Furthermore, the presence of cobalt in an electrolyte restrains the migration of lead from the anode to the cathode, and therefore improves the grade of the zinc deposit.

A considerable amount of data has been accumulated in relation to the effect of cobalt. It is, however, a subject



FACTORS AFFECTING CURRENT EFFICIENCIES OF COBALT BEARING SOLUTIONS

which is intensely interesting and will well repay further study.

For some years the Risdon plant operated on a solution containing 70 mgs. or more of cobalt per litre, and electrolysis was conducted on a 72 hour deposition period with a spent electrolyte containing 65 grams per litre acid, and using 5 to 3 lbs. of glue per ton of cathode zinc deposited. Two years ago the procedure was modified, and the electrolyte now contains only 10 mgs. of cobalt per litre and electrolysis is conducted at 90 grams acid per litre using approximately 1 lb. of glue per ton of zinc deposited. This change, coupled with a reduction in electrode spacing, has enabled the Risdon zinc output to be increased by nearly 10% and, in addition, the structure of the cathode zinc has improved. It is emphasized, however, that the optimum amount of glue addition is dependent on the composition of the electrolyte, and it by no means follows that the conditions found best at Risdon will be applicable to every other solution.

*Nickel.* Some zinc concentrates contain nickel, which dissolves during the leaching of the calcine. It is toxic even in the absence of cobalt, but more so if cobalt be present. Up to 25 mgs./litre of nickel can be tolerated with little effect on current efficiency, provided cobalt and antimony are low and glue is used. With a solution containing 70 mgs. of cobalt, which, without nickel but with glue yields excellent current efficiencies, 5 mgs. of nickel will cause a drop in efficiency. The amount of nickel in Broken Hill concentrates is insignificant.

*Antimony.* This impurity shares with cobalt the responsibility for the failure of the early efforts to establish the electrolytic zinc process on a commercial basis, and even since 1914 it has been subjected to considerable verbal

and literary abuse, some of which it undoubtedly deserves. Under certain conditions, however, it has beneficial properties, and for some time antimony was deliberately used at Risdon as an addition agent to maintain the amount of antimony in the electrolyte between 0.2 and 0.3 mgs. per litre.

Zinc deposited from electrolyte containing antimony is rough in structure, and the extent of roughness increases with increasing antimony content. This roughness is particularly in evidence with cobalt-bearing solutions using glue as an addition agent. Figure 7 illustrates the effect of antimony on the structure of cathode zinc. The bulk solution used when producing each of these cathodes was high cobalt Risdon Works solution, from which antimony, arsenic and copper had been removed, and a pure antimony salt then added as required in each case. It contained 80 mgs. cobalt and 100 mgs. glue. The deposition period was 72 hours at 30 amperes/sq. ft., and the temperature was 35°C.

The overall current efficiency when operating with a six-cell series, with 55 grams acid in the first five cells and 65 in the last, would be approximately:—

With less than 0.1 mg. antimony	88% to 90%
With 0.3 mg. antimony .. ..	93%
With 0.5 mg. antimony .. ..	94%

A variation in the nature and amount of the other impurities would naturally affect the electrolytic behaviour of the solution.

A higher antimony concentration reduces current efficiency, and with the cobalt and glue concentration specified, the optimum amount of antimony is between

0.2 and 0.3 mgs./litre, because with higher amounts the reduction in melting efficiency offsets the gain in current efficiency.

The relationship between cobalt, antimony and glue is obscure, and it is a subject which justifies further investigation.

In a solution free from cobalt or containing a small amount only, antimony has an effect on the structure of the zinc, and it lowers current efficiencies when present in appreciable amounts. The maximum permissible amount varies according to the nature and quantity of other impurities present.

*Arsenic.* In solutions practically free from cobalt and antimony, arsenic is not very troublesome, but with solutions containing 70-80 mgs. of cobalt per litre and some antimony, less than 1.0 mgs. per litre arsenic has a disastrous effect.

Figure 8a illustrates the cathode zinc produced from a solution free from cobalt and antimony, but containing 5 mgs. arsenic/litre. The current efficiency was over 92% after 72 hours deposition at 100 grams acid/litre.

Figure 8b is a photograph of a zinc deposit produced from solution containing 70 mgs. cobalt and 1 mg. arsenic per litre. The holes are characteristic of arsenic and cobalt together. Despite the presence of glue, the current efficiency was very low after 72 hours at 65 grams acid. The same solution, without arsenic, would have yielded a current efficiency of 88% or better.

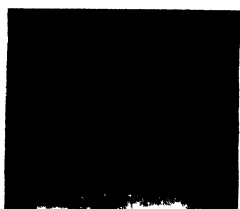
In a series of tests using glue and the standard 72-hour deposition period with acidity of 55 and 65 grams per litre, the following efficiencies were obtained:—



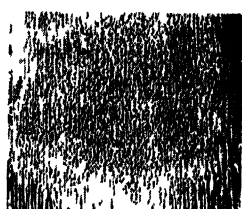
(a)

Fig 6

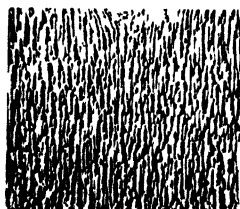
(b)



(a)

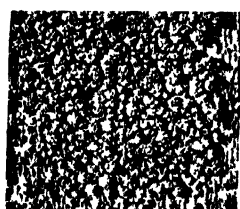


(b)



(c)

Fig 7



(d)



(a)

Fig 8.

(b)





No arsenic	..	..	..	..	..	..	90%
0.25 mgs. per litre arsenic	..	..	..	..	..	..	81%
0.5     "     "     "     "	..	..	..	..	..	..	73%
1 mg.     "     "     "     "	..	..	..	..	..	..	66%

*Copper.* Copper is easily removed during treatment of the solution with zinc dust, and a very small amount only is usually present in most commercial electrolytes. With 70-80 mgs. of cobalt, 0.5 mgs. of copper is harmful under some conditions, particularly with increasing acidity of electrolyte and age of deposit. With 10 mgs. cobalt, this amount has little or no effect.

*Germanium.* Germanium has recently been found in the electrolyte in some of the American plants.<sup>(f)</sup> This impurity is normally removed during the co-precipitation of the antimony, arsenic and iron. In the absence of sufficient iron, removal of germanium is incomplete, and electrolytic troubles arise. According to Tainton, 0.1. mg. per litre seriously reduces current efficiency. It is possible that antimony has hitherto been blamed for some of the electrolytic effects of germanium.

Other elements have some effect and selenium is notable in that whilst it reduces current efficiency, the zinc produced in its presence is bright and silvery in appearance.

### Electrodes.

The condition of the electrodes is important, and one of the major items of expenditure in connection with the electro-deposition of zinc is the cost of replacing anodes and cathodes.

*Anodes.* Pure lead is used in most plants for anodes, but lead containing 1% silver, and in some cases a little arsenic, is used in the Tainton process. The anode potential

is lower and the cathode zinc contains less lead when lead-silver anodes are used.

Lead containing various amounts of antimony was used in a few cells at Risdon some time ago, primarily as a means of maintaining the optimum amount of antimony in the electrolyte. The zinc produced in the cells using these anodes was rough in structure, and was characteristic of cathodes deposited in the presence of antimony. Despite considerable research by the Risdon staff, using various alloys containing lead as the major constituent, and also with other alloys, no anode material has been developed which is superior to lead.

All lead anodes become distorted during use, and it is a routine duty to keep them straight and spaced correctly. The attention required increases with age, but apart from this there is a relationship between anode age and current efficiency, and it is therefore usual to discard anodes before they are mechanically unsound. This relationship is probably due in some way yet undetermined to intercrystalline penetration by lead peroxide, and possibly other substances. The extent of this penetration is probably partly dependent on the composition of the electrolyte.

Hydrochloric acid in solution corrodes the anodes, and it is mainly on this account that its concentration is maintained at a low figure.

Under the old Risdon conditions the optimum life of anodes is about three years, but the corresponding figure with the Risdon low cobalt solution has yet to be determined. Discarded anodes are re-melted, and the reclaimed lead, amounting to 60 to 70% of that originally in the anode, is utilised for new anodes.

*Cathodes.* Sheet aluminium is universally used as the base on which to deposit zinc, although attempts have been

made to use zinc sheets. Aluminium-silicon alloy sheets have also been investigated at Risdon. Corrosion of the aluminium above the solution line largely determines the life of the cathode. There is always more or less spray immediately above the electrolyte, and some of this condenses on the unsubmerged portion of the cathode. Furthermore, the solution creeps up the surface, and as the cathode is warm, water is evaporated and acidity increases with consequent acceleration of the corrosion. At some plants the effective life of aluminium is little more than one year, when the cathodes are discarded and sold as scrap.

An investigation extending over several years has been conducted at Risdon to determine the most satisfactory way of counteracting corrosion, and for some time it has been the practice—

- (1) To use sheets which are thicker in the unsubmerged portion, and
- (2) To further protect this by coating it with a thin deposit of zinc to within an inch or so of the head bar by simply increasing the solution level above normal in a series of cells, in which all the cathodes are electroplated with zinc periodically.

As a result of this strengthening and protection, the cathode life at Risdon was 4 years, until the acidity of the electrolyte was increased two years ago, since when corrosion has been somewhat more marked. There has thus been a further incentive to prosecute the investigation with renewed vigour, and a large number of varnishes, including Bakelite, also rubber and gutta percha, have been applied in a number of different ways without a great deal of success. Covering with lead has been par-

tially successful, but the most satisfactory method is to rivet an aluminium strip reclaimed from discarded cathodes over the unsubmerged portion of the cathodes in use. This procedure is still under test, but it appears likely that it will become standard practice, and the future life of the cathode will probably be determined by the corrosion of the submerged sheet, particularly the edges. This is equivalent to a life of approximately 7 years.

### Melting and Casting.

All cathode zinc contains oxygen, and some zinc oxide separates when the cathodes are melted, the amount depending on the structure of the deposited zinc and on the oxidation of zinc during melting.

Two products are recovered—molten zinc and dross—the latter being a mixture of metallic zinc, zinc oxide and coal ash. To facilitate the separation of dross from the molten zinc, it is customary to add a small amount of ammonium chloride. After removal from the melting furnace the dross, whilst still hot, is treated with more ammonium chloride, and most of the metallic zinc is liquitated or “sweated” away from the oxide. Finally, after the remaining metal in the dross has solidified, the dross at Risdon is given a light grind, is screened, and the oversize particles, which are mainly metallic zinc, are returned to the melting furnace. This final dross treatment stage yields 1 ton of metallic zinc per day.

The ammonium chloride used at Risdon totals 2lbs./ton of cathode zinc melted.

The melting efficiency, which is the yield of zinc in ingot form expressed as a percentage of the cathodes melted, has now reached 96.6% at Risdon.

### Treatment of Residues.

Some of the residues obtained during leaching and purification contain valuable products. Such residues are:—

- (1) The leach residues, which retain most of the lead, silver and some of the zinc originally in the roasted zinc concentrates.
- (2) The precipitate obtained by treating the solution with zinc dust. This precipitate contains most of the copper and cadmium dissolved during leaching.
- (3) The cobalt nitroso beta naphthol precipitate obtained by treatment of that portion of the solution from which cobalt is removed. It is contaminated with zinc sulphate.

### *Leach Residues.*

Various methods have been proposed for recovering zinc from the zinc ferrite in the leach plant residues. Amongst these are:—

- (a) Prolonged leaching with hot 10% sulphuric acid.
- (b) Treatment with concentrated sulphuric acid and roasting.
- (c) Modification of (b) in which roaster gases containing sulphur dioxide are substituted for sulphuric acid, and
- (d) Reduction of the ferrite with carbon at a high temperature, and volatilisation of the zinc.

During the leaching with sulphuric acid (Method (a)), the ferrite is decomposed with the formation of zinc sulphate and ferric sulphate, which dissolve. Zinc oxide (as calcines), is added to the solution, and the iron is precipitated as basic sulphate, which is difficult to filter and wash, and contains much adsorbed zinc sulphate.

Method (b) is based on the fact that the decomposition temperature of iron sulphate is lower than that of zinc sulphate. In practice acid equivalent to the zinc contained in the ferrite is mixed with the residues, and approximately 40% of the ferrite is decomposed, forming sulphates of iron and zinc. The mixture is heated to a temperature between 650° and 700°C when the iron sulphate decomposes into ferric oxide, and a mixture of sulphur dioxide and trioxide which attacks further ferrite. This cycle is repeated until the whole of the ferrite is converted to zinc sulphate and ferric oxide. The zinc sulphate is dissolved and the solution is added to the main circuit.

In method (c), the hot gases containing sulphur dioxide produced during the roasting of zinc concentrates are passed through the residue maintained at 650-700°C. The end products are much the same as those obtained when roasting with sulphuric acid.

In both methods (b) and (c), zinc is introduced into the circuit as sulphate, and either the sulphate concentration or the volume of the solution increases, unless sulphuric acid in some form or other is discarded from the circuit.

Residues are being leached with sulphuric acid at one plant, and are roasted with acid at another. The fourth method has been proposed from time to time, but as far as the author knows, has not been used commercially for the treatment of leach plant residues. A modification of the process based on roasting the residue with sulphuric acid, has been developed for the treatment of Risdon residues, but whether it is used or not will depend largely on the future price of zinc.

#### *Copper-Cadmium Residues.*

The "zinc dust" precipitate contains copper and cadmium, zinc and some silver, and is usually treated for re-

covery of cadmium metal, zinc sulphate solution which is returned to the zinc plant circuit, and a concentrated copper residue containing silver.

The "zinc dust" precipitate produced at Risdon contains:—

Cadmium .. ..	11–16%
Copper .. ..	8–10%
Zinc .. ..	28–32%
Silver .. ..	20–50 ozs.

The precipitate is leached in zinc plant electrolyte under conditions whereby most of the zinc and cadmium dissolve together with a small amount of copper. Most of the copper and silver remain in the residue which is filtered, washed, dried and sold.

The resultant solution is agitated with a controlled amount of zinc dust to precipitate cadmium and copper. After separating the solids, the solution is returned to the zinc plant circuit. The precipitate is partly oxidised by drying, and is leached with cadmium plant spent electrolyte. The resulting cadmium sulphate solution is purified and electrolysed. The cadmium cathodes are melted under a flux.

The Risdon production of cadmium is 200 tons per annum.

### *Cobalt Precipitate.*

Cobalt-nitroso beta naphtholate has certain desirable properties as a paint pigment and it is likely that its use for this purpose will become established within the near future.

### GENERAL.

The industry owes much to research, which in its widest sense relates to electrical, mechanical and chemical engineering, in addition to pure chemistry and physics. In



this connection, it is perhaps not generally appreciated how difficult it sometimes is to interpret the information obtained from laboratory experiments and to use it to improve an industrial process. The first stage in the development of a modification of process frequently involves a large number of experiments in the Work's laboratory, using Work's solution; next comes the development of the technique for maintaining in the plant the optimum conditions determined in the laboratory. An economic study of the laboratory results is then necessary, and in many cases, plant has to be provided, or else the existing plant modified.

The evolution of a process modification from laboratory results is frequently tedious and is a responsible duty. This is particularly true when an alteration of solution composition is under consideration. If done thoroughly, it is undoubtedly an essential part of the research, and without it technical progress would be impossible.

Brief reference has already been made to specific changes in practice developed from research work. The improvement in the Risdon results during the past five years, as shown by various key figures, illustrates the general benefits derived from research work, and from the very rigid control of plant operations to conform with the optimum found during such research work.

The figures for the year ended June, 1926, are compared below with those realised during the year ended June, 1931:—

	Year ended June, 1926.	Year ended June, 1931.
1. Current Efficiency . . . . .	88.8%	91.6%
2. Yield of Zinc/H.P. Day D.C. in lbs.	10.95	12.23
3. Zinc Dust used for precipitation of Copper and Cadmium in lbs./ton cathode zinc . . . . .	42	19
4. Melting Efficiency . . . . .	94.1	96.6%

The author desires to emphasize here, that in the production of electrolytic zinc, and to a greater extent, perhaps, than in the production of any other metal, extraordinarily close control is essential for high efficiency. The process is continuous and operates through every hour of every day in the year. When one realises that small variations in the composition of the electrolyte can produce widely different results, it is evident that the maintenance of high efficiency calls for the closest attention on the part of metallurgists, chemists and operatives generally.

There is still a lot of work to be done before there is a complete understanding of all the reactions which occur during the conversion of zinc sulphide to electrolytic zinc. This is particularly true of the reactions occurring in the cell, and it would be useful to have precise information on the four following matters:—

- (1) The reason for the observed effects of toxic impurities;
- (2) The manner in which glue and other addition agents restrain the toxicity of cobalt and similar impurities;
- (3) The anode reactions, with particular reference to the effect thereon of impurities introduced in the cell feed, and,
- (4) The reason why impurities—and antimony in particular—modify the structure of the deposited zinc.

All these matters have had attention at the various electrolytic zinc plants and in university laboratories—in many cases by the various zinc companies' own staffs working there. These reactions are still, however, somewhat imperfectly understood, and there is need for further work.

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#### EXPLANATION OF PLATE.

Fig. 6.—Cathode zinc after 19 hours deposition from electrolyte containing 70 mgs. cobalt/litre, (a) without glue, (b) with glue. (See Page M34.) X1/6.

Fig. 7.—Cathode zinc showing effect of antimony in electrolyte (a) Nil Sb, (b) 0.1 mgs. Sb/litre, (c) 0.3 mgs. Sb/litre, (d) 0.5 mgs. Sb/litre. (See Page M37.) X1.

Fig. 8.—(a) Cathode zinc produced from solution free from cobalt and antimony but containing 5 mgs. arsenic/litre, (b) Cathode zinc produced from solution containing 70 mgs. cobalt and 1 mg. arsenic/litre. (See Page M38 ) X1.

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